SQUAMISH ESTUARY MANAGEMENT PLAN

Habitat Work Group Final Report

February 1981

Government of Canada
Gouvernement du Canada

Province of British Columbia

BACKGROUND PUBLICATIONS

SQUAMISH ESTUARY MANAGEMENT PLAN

Air and Water Quality Work Group
Final Report

Habitat Work Group
Final Report

Land Use Work Group
Final Report

Recreation Work Group
Final Report

Squamish Estuary Draft Management Plan

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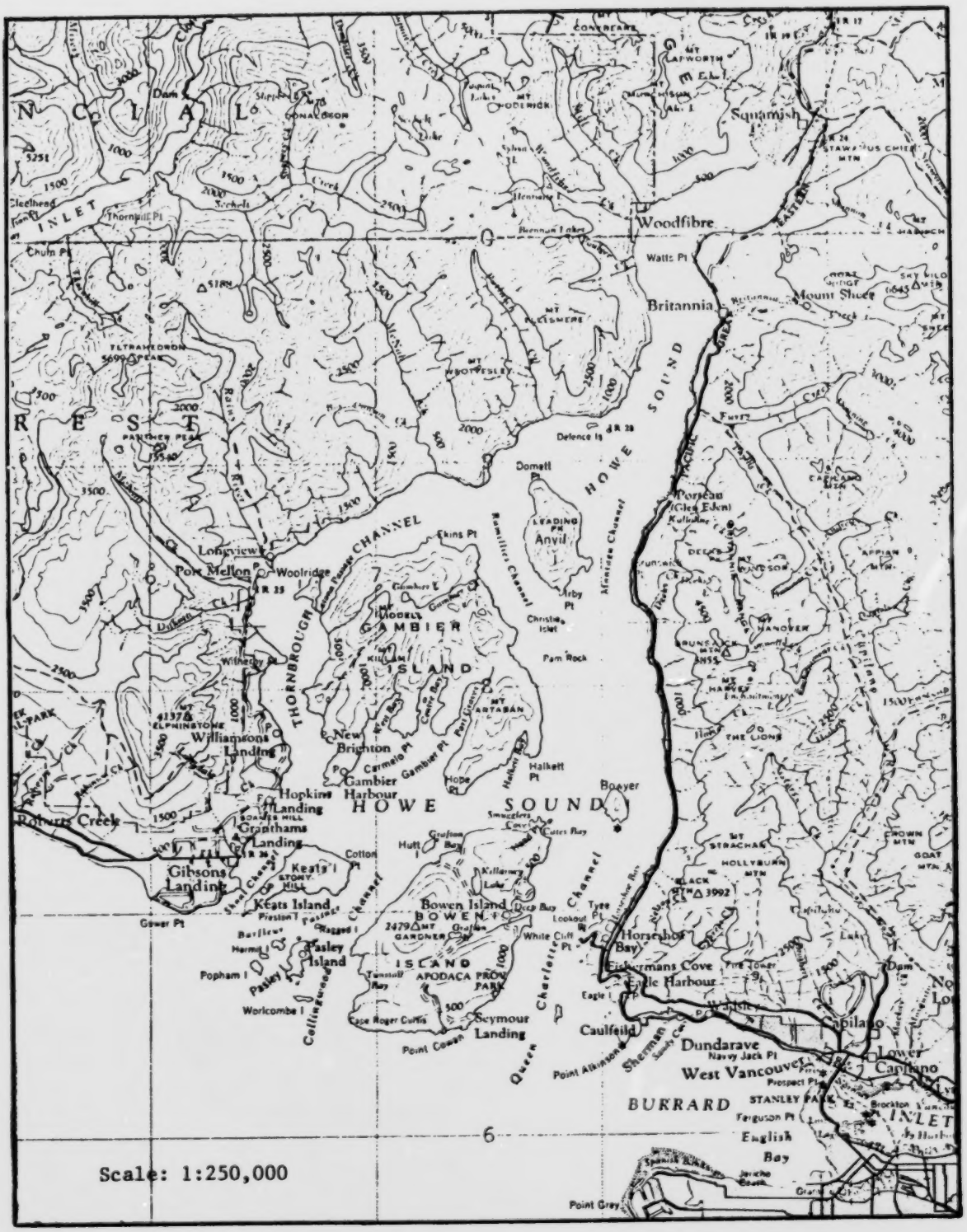

SOME PLACE-NAMES MENTIONED IN THE TEXT

1.0 INTRODUCTION

1.1 History of Study

The Squamish River Estuary Management Study was initiated in May of 1979, by the Federal and Provincial Governments to develop a management plan for the lower Squamish River and estuary.

The study encompassed land use, recreation, habitat for fish and wildlife, and air and water quality. Four technical work groups, directed by a Federal-Provincial Planning Committee, were organized to prepare both interim and final reports on each of the subjects.

1.2 Study Boundaries

The study area (Figure 1) encompasses the Squamish River downstream from the Mamquam River, as well as the estuary area to the five fathom contour off the delta front.

1.3 Objectives of the Habitat Work Group

Within the study terms of reference, the Habitat Work Group was delegated to compile and analyze existing data regarding habitat types and their use by fish and wildlife in the study area. The information contained within this report was compiled from existing sources, except for data on the classification and distribution of habitat zones. It was necessary to collect habitat zone data in order to classify various habitats adequately.

The specific terms of reference for the Habitat Work Group were as follows:

PHASE I

1) Delineate the present terrestrial, intertidal and aquatic habitat zones.

2) Identify: Marine, brackish and freshwater areas; terrestrial, emergent and submerged plant associations; primary productivity indices; benthic invertebrate populations.

3) Identify the natural riverine and oceanographic factors affecting the physical substrate.

4) Describe the fishery resource base and its commercial and recreational use.

5) Describe the level of habitat utilization and the distribution and periodicity (where applicable) of use by fish stocks.

6) Describe the wildlife resource base and its commercial use.

7) Describe the level of habitat utilization and the distribution and periodicity (where applicable) of use by wildlife populations.

8) Identify areas formally designated for fish and/or wildlife protection.

9) In conjunction with the Land Use Work Group, identify past land use practices and industrial and urban developments and activities which have decreased or increased the productive capacity of the aquatic fisheries environment, and of terrestrial and aquatic wildlife environments.

10) a) Identify information gaps.

b) Identify current problems and conflicts (Habitat/Fisheries/Wildlife).

PHASE II

11) Identify habitat maintenance, restoration and enhancement opportunities.

12) Outline habitat requirements for major species or groups, identify levels of habitat-oriented dependency, food chain relationships, water quality for fish stocks.

13) Outline habitat requirements for major species or groups, identify the level of habitat-oriented dependency in terms of food, space, water quality, etc. for wildlife populations.

PHASE III

14) Describe integrated resource use potentials for all major habitat types.

15) Make recommendations concerning opportunities for the maintenance, restoration and enhancement of habitat. This to include the identification and priorization of means of resolution/mitigation of current problems and conflicts as identified in Phase I item 10(b).

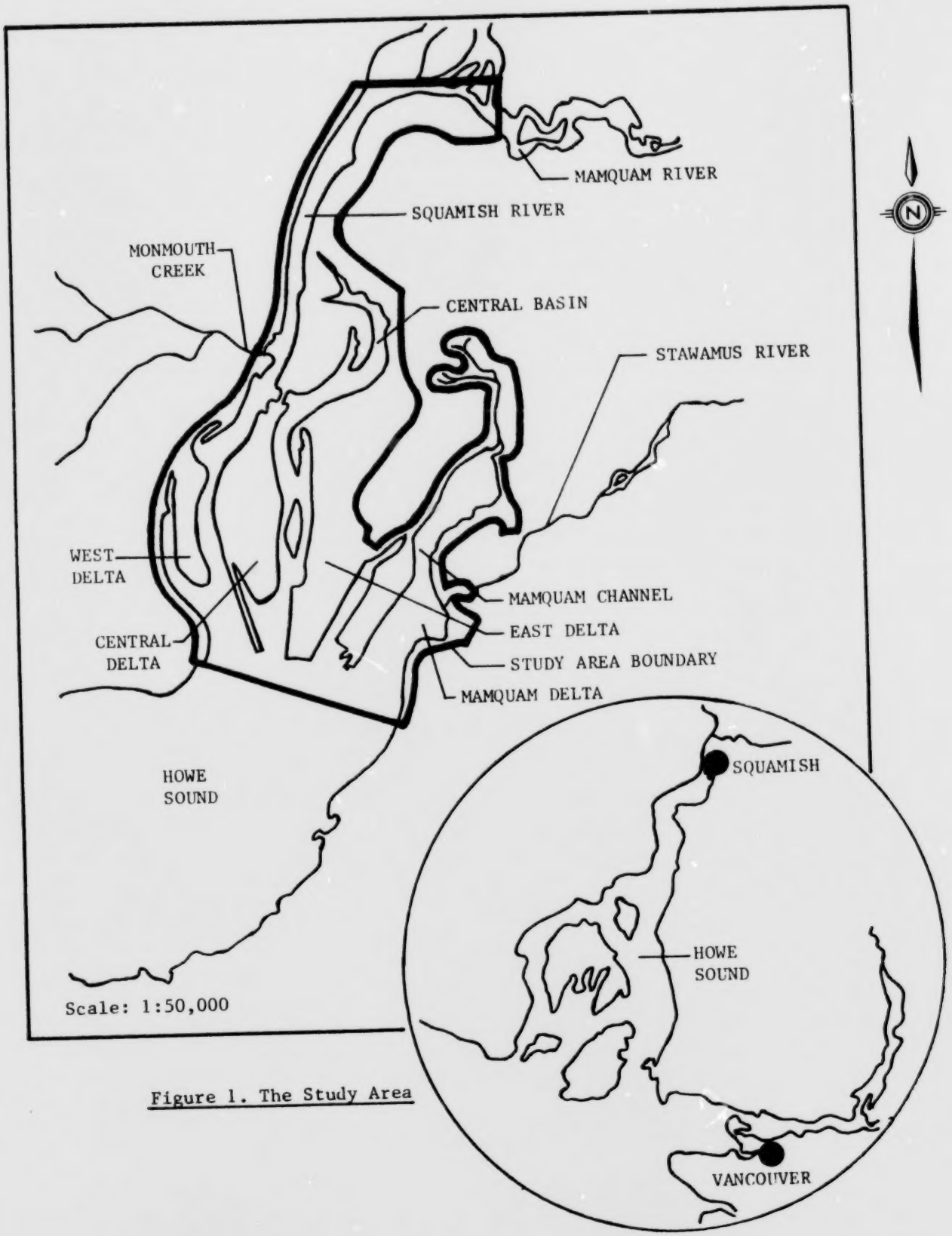

Figure 1. The Study Area

2.0 OVERVIEW OF RESOURCE BASE

2.1 Marine, Brackish and Freshwater Areas

Howe Sound has a long history of oceanographic observations beginning with studies by Carter (1934) in the 1920's. The Pacific Oceanographic Group (1953 and 1954) included Howe Sound in their studies of the oceanography of the Strait of Georgia in the late 1940's and early 1950's and Pickard (1961) included Howe Sound in his studies of British Columbia coastal inlets. Monitoring of the waters along the heavily populated and industrialized Lower Mainland began in 1957 and was extended into Howe Sound in 1959 and years thereafter to 1966 (Waldichuk et al., 1968). Much of this information was summarized by Waldichuk (1972) and Giovando (1972). Syvitski (1978) collected further oceanographic information in his study of sedimentation processes in Howe Sound.

Crean and Ages (1971) included Howe Sound in their numerical modelling studies of water circulation in the Strait of Georgia. Bell (1973 and 1974) summarized historical oceanographic data and collected more in 1972 to determine the mechanism of water exchange behind the sill of Howe Sound. Buckley and Pond (1976) and Buckley (1977) investigated the relative effects of wind, tide, and river runoff on the circulation of the surface water layer of Howe Sound.

Water temperature, salinity, and dissolved oxygen concentration measurements were made from September 1972 to September 1973 (Levings, 1976) and from February 1974 to January 1975 (Levings et al., 1976) on the Squamish River delta during studies to determine the effect of river diversion and industrial development on benthic communities.

Sources of fresh and salt water are the fundamental determinants of the distribution of fresh, brackish, and marine zones in the estuary. The main input of fresh water into the Squamish estuary study area is from the Squamish River and its two main tributaries, the Cheakamus and Mamquam Rivers. The Stawamus River, which enters the delta via Mamquam Channel, contributes a relatively minor volume of fresh water (Hoos and Vold, 1975).

Figure 2 is the mean annual hydrograph for the Squamish River below Mamquam River obtained by averaging flows over four years from 1974 to 1977. In addition to the June to August freshet peak are a number of storm peaks in late fall and early winter (Zrymiak and Durette, 1979). Levings (1976) reported, from Water Survey of Canada data, a mean annual flow for the Squamish, Cheakamus, and Mamquam Rivers combined of 290 m^3 $sec.^{-1}$*. Maximum flows in the neighbourhood of 820 m^3 $sec.^{-1}$ usually occur in June and minimums of 70 m^3 $sec.^{-1}$ in March (Hoos and Vold, 1975). Abnormally warm weather and heavy rain in the last week of December 1980 resulted in floods in the Squamish area approaching the 80-100 year flood stage. Flows during the flooding could not be measured because the river had overflowed its normal channel (Eliasen, 1981 MS).

The source of salt water input to the Squamish estuary is the Strait of Georgia where salinity levels are generally below 29 parts per thousand due primarily to dilution by the Fraser River (Waldichuk et al., 1968).

Howe Sound is a typical estuarine system where there is a net seaward flow of a surface fresh water layer over more dense marine layer. Friction between the two layers results in the entrainment of marine water into the surface layer so that it becomes increasingly saline as it moves down the Sound. Movement and mixing of marine and fresh water is affected by the variable factors of river runoff, wind speed and direction, daily fluctuations in tides, and horizontal differences in water density. Constant factors such as river depth, deflection of flow by natural and man-made structures, and the Coriolis effect also affect movement of fresh water (Habitat Work Group, Fraser River Estuary Study, 1978).

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*Notation for cubic meters per second.

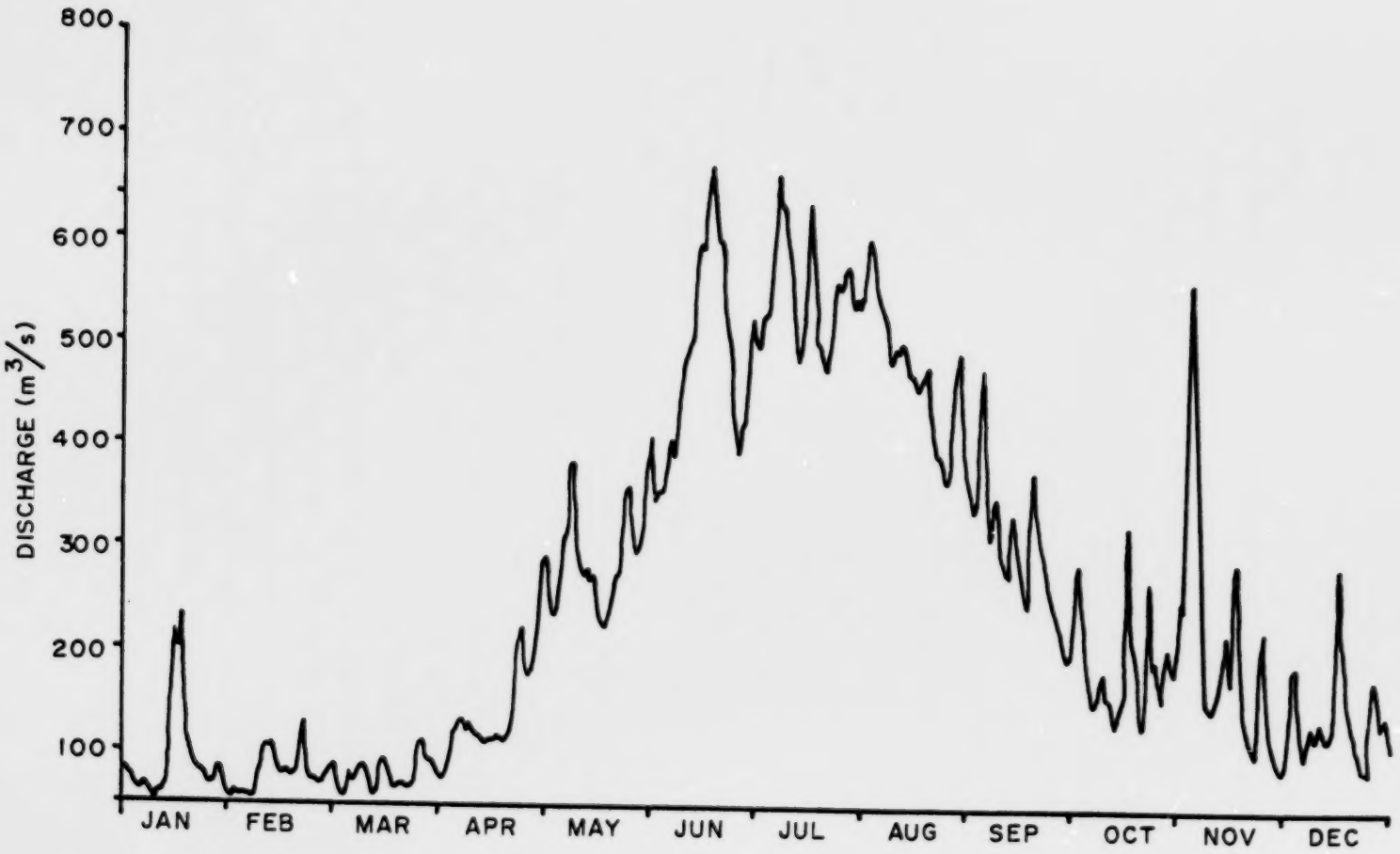

Figure 2. Squamish River Mean Annual Hydrograph, Station 086A054 plus 086A022, 1974-77 (from Zrymiak and Durette, 1979)

Buckley and Pond (1976) conducted an experiment to determine the relative effect of the above factors on surface water circulation in Howe Sound. Their experiment determined that the wind is the dominant force moving the surface layer and that the large daily variation in wind velocity causes a variability in surface currents an order of magnitude greater than could be accounted for by river runoff and tides. River runoff was also an important factor. When wind effects were averaged out of surface flows, circulation patterns bore resemblance to silt patterns observed in aerial photographs, that is, river water flows into Howe Sound in a southerly direction, in line with the axis of the west channel training wall, and is deflected to the west by the point where Howe Sound makes a right angle bend. The northeast corner of Howe Sound, including Mamquam Channel, is bypassed by the initial impact of fresh water.

Entrainment of marine water into the seaward flowing surface brackish layer results in an up-inlet flow of marine water below the surface layer. Penetration of this marine water into the river mouth is determined by daily tidal fluctuations and seasonal variations in river runoff. During periods of low river runoff, a salt wedge can be detected up the river channel approximately 1.5 km from the mouth. When the runoff is high, i.e., greater than $500\ m^3\ sec.^{-1}$, the salt wedge does not penetrate the mouth of the river (Levings, 1980a).

Despite variations in salinity distribution due to factors mentioned above, it is possible to identify areas on the Squamish delta influenced more by fresh water than others. Generally, areas near the river mouth and shallow areas are less saline than deeper sites. Because fresh water input is restricted to the west side of the delta by a training dyke constructed in 1972, water of the West delta is less saline than that of the East and Central deltas and Mamquam Channel. Culverts, which were installed in the training

dyke about 3 km above the mouth of the Squamish River, allow a freshwater lens to develop in the Central basin during high flows, but this lens does not penetrate to the seaward edge of the basin (Levings, 1980a). Under low flow conditions salt water was detected up the Central basin and Mamquam Channel as far as measured which was approximately 1.5 km and 1 km respectively (Levings et al., 1976).

The distribution of salinity in surface waters of the Squamish River estuary is presented in Figures 3 and 4. February, 1973 is during the low flow period; December, 1974 is during a moderately high flow period.

2.1.1 Information Gaps

Gaps exist in the salinity data collected by Levings et al., (1976). For instance, December 1974 was the only sampling time when all areas of the delta were sampled. The same detail of sampling would be of more value if conducted during March (low flow) and June (high flow).

2.2 Substrates

Sediment characteristics of the Squamish River delta were described by Bell (1975) and Levings (1980a). Studies of the factors which influence sedimentation were conducted by Zrymiak and Durette (1979) in the lower Squamish River, by Bell (1975) on the delta, and by Syvitski (1977) in Howe Sound.

In order to assess the impact of river training and dredging on the estuary, a long term morphological study of the lower five kilometers of the Squamish River was initiated in 1972 (Zrymiak and Durette, 1979). From 1973 to 1974 considerable erosion occurred in the river channel downstream of the Mamquam River to the culverts. Narrowing of the channel, resulting in increased river flows, was responsible for the erosion, but in 1978 the area was considered stable. From the culverts down to the mouth of the river channel there was a net accretion of sediment from 1973 to 1978 with the result that the dredged channel was completely filled by 1978. Some erosion and

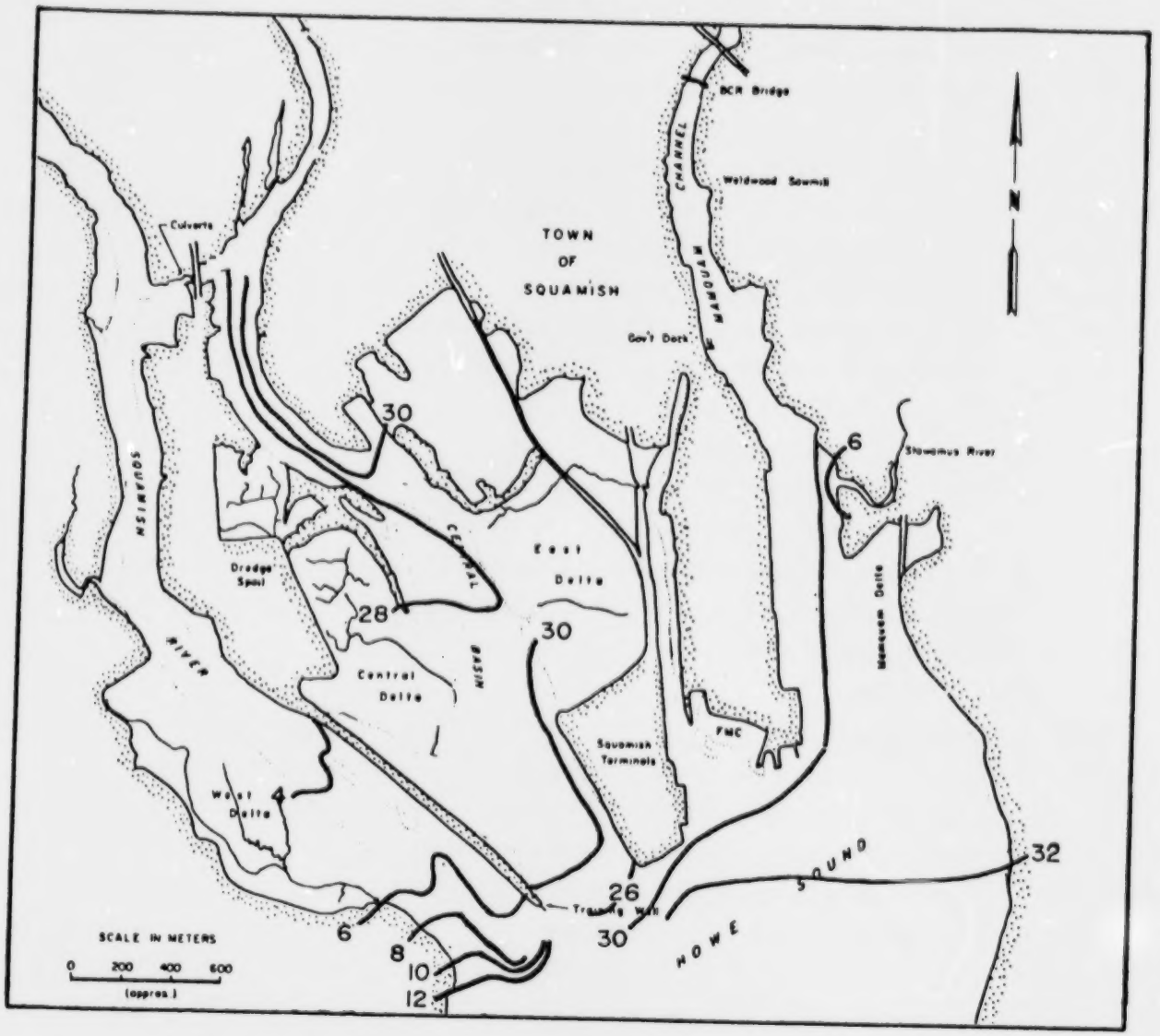

Figure 3. Squamish River Estuary Surface Distribution of Salinity - February 1973 (from Levings et al., 1976)

slumping occurred on the northwest bank of the channel due to the migration of the river curve downstream. The lower portion of the West delta advanced at a steady rate between 1973 and 1978.

Bell (1975) divided the Squamish River delta into three zones, the intradelta (intertidal marshes, lower intertidal flats, and rivermouth bars), the delta front (0 m to 50 m depth), and the prodelta (beyond the 50 m depth). Figures 5 and 6 are maps of the substrate distribution on the intradelta and delta front, respectively.

Factors generally influencing deltaic sedimentation are described in Table I. Bell (1975) considered how these factors affected sediment distribution on the delta at Squamish.

Bell (1975) observed that sedges trapped considerable amounts of silts and clays carried in suspension by the river with the result that sediments in tidal marshes were dominated by silty-clays with small amounts of clay.

Sediments of the lower intertidal flats on the West delta were coarser than those of the Central delta. Bell (1975) suggested that sediment deposition and distribution in this zone is a result of:

1. A higher energy environment on the West delta due to greater river flows and the protection of the Central delta by the training wall from waves during strong southerly winds.

2. Differences in salinity regimes between deltas and intrusion of the salt wedge as a result of deepening of the west channel.

River mouth bars were confined by construction of the training wall to the West delta where a large submerged bar has been building since the channel was dredged in 1972.

The delta front is covered by sandy-silts. In the western sector, sands predominate, whereas, in the eastern sector, there is a higher proportion of silt and clay, probably attributable to flocculation. Comparison of 1930 and 1973 bathymetric charts indicated that confinement of river flow to the West delta is resulting in rapid accretion

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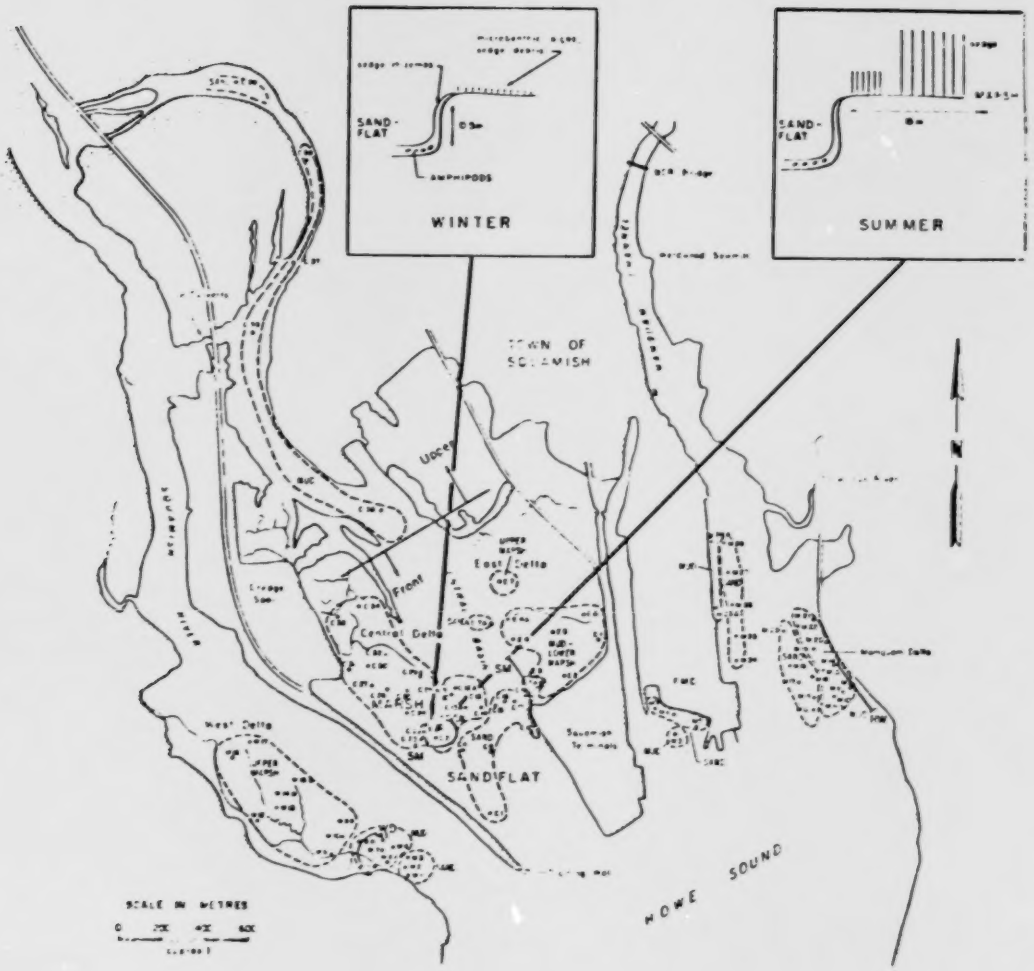


Figure 5. Sediment Distribution on the Intradelta of the Squamish River Estuary. *Inserts show detail of embankment and sedge rhizome habitat at the seaward edge of the Central delta.* (from Levings, 1980b)

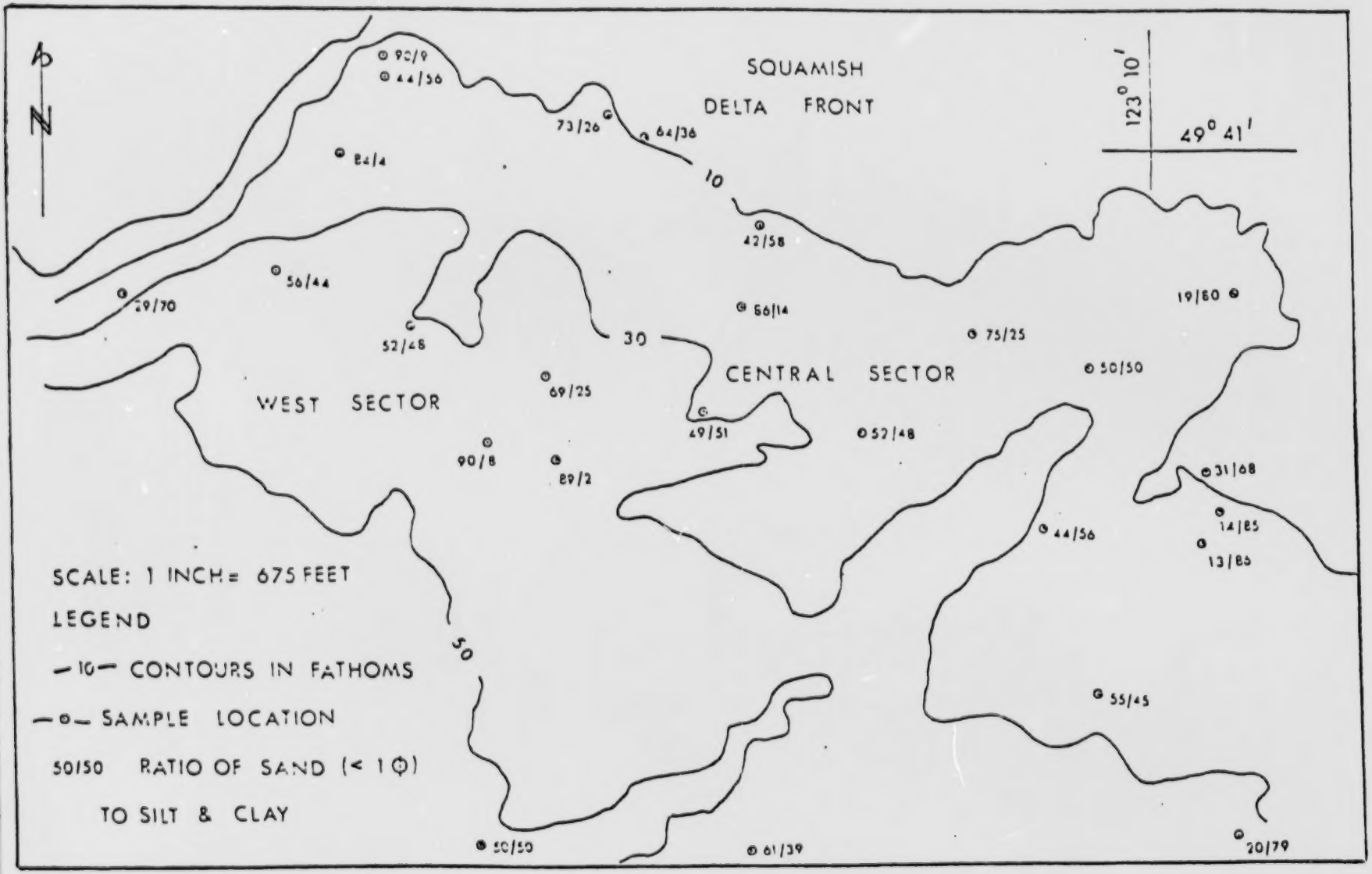


Figure 6. Location of Sediment Samples - Delta Front (from Bell, 1975)

TABLE I: FACTORS INFLUENCING DELTAIC SEDIMENTATION

RIVER REGIME	FLOOD STAGE	SEDIMENT LOAD	Quantity of suspended load and bad load (that is, stream capacity) increases during flood
		PARTICLE SIZE	Particle size of suspended load and bed load (that is, stream competence) increases during flood
	LOW RIVER STAGE	SEDIMENT LOAD	Stream capacity diminishes during low river stage
		PARTICLE SIZE	Stream competence diminishes during low river stage
MARINE PROCESSES	WAVE ENERGY		High wave energy with resulting turbulence and currents, erode, rework and winnow deltaic sediments
	TIDAL RANGE		High tidal range creates tidal currents and influences deposition in the intertidal zone
	CURRENTS		Currents generated by waves and tides, density and turbidity currents provide mechanism for sediment transport
CLIMATIC FACTORS	SEASONAL EFFECTS		Quantity of fresh water supplied by the river varies with amount of run-off from rain or melting snow. Water temperature variations affect settling rate of suspended sediment
	WET AREA	HOT OR WARM	High temperature and humidity yield dense vegetative cover which aids in trapping sediment transport by fluvial or tidal currents
		COOL OR COLD	Seasonal character of vegetative growth is less effective in sediment trapping - cool winter temperature allows seasonal accumulation of plant debris to form delta plain peats

from Bell, 1975

on the West delta front (approximately 6.5 metres per year) while the East and Central delta front is showing signs of erosion (Bell, 1975).

2.3 Plant Associations and Primary Productivity

The vegetation resource of the Squamish estuary has been studied extensively since the Federal-Provincial Task Force on the Squamish Estuary Harbour Development was established in 1971. The nature of the primary and secondary components of the food web of the outer Squamish estuary was assessed by Cliff and Stockner (1973) with emphasis on phytoplankton production. A mathematical model of phytoplankton growth and distribution as a function of biological and physical conditions in Howe Sound was developed by Buchanan and Stockner (1976) based on four years study of phytoplankton production in the Sound. In relation to natural and man-induced factors which affect the light regime in the surface layers of Howe Sound, Stockner et al. (1977) examined phytoplankton production and distribution over a period of two years.

Information on growth and distribution of benthic algae on the Squamish River delta was collected by Pomeroy and Stockner (1972), Pomeroy (1974), and Pomeroy and Stockner (1975). Primary productivity and energy flow, with emphasis on benthic algae, was studied by Pomeroy (1977 and in prep.). Prange (1978) determined the environmental factors responsible for the distribution and growth rates of a benthic alga, Blidingia minima var. subsalsa, on the delta.

A description of the vascular plant communities including vegetation maps, species lists, and biomass data was obtained in studies by Howard Paish and Associates Limited (1972) and Lim and Levings (1973). Levings and Moody (1976) determined standing crop values and net primary production for Carex lyngbyei on the delta in 1974. Recovery of vegetation which was smothered in 1972 by dredge spoil, was assessed by Levings and Moody (1976) and Kennedy (1978).

Terrestrial vegetation of the Squamish delta has been described by Orloci (1961) and Howard Paish and Associates Limited (1972).

2.3.1 Submergent Macrophytes

Lim and Levings (1973) reported that no eelgrass (Zostera spp.) beds exist in the Squamish estuary study area. However, one patch of eelgrass was observed on the Mamquam delta in June 1973 (Levings, 1976).

2.3.2 Pelagic and Benthic Algae

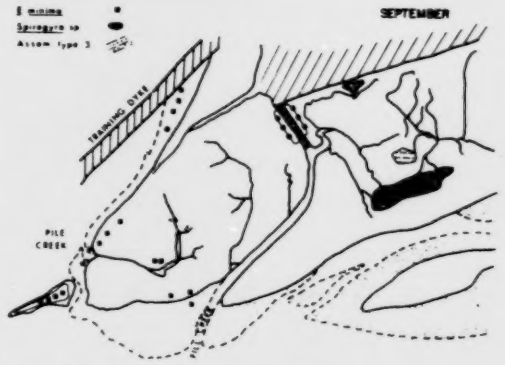
Stockner et al. (1977) determined that phytoplankton production in Howe Sound decreased linearly in an up-inlet direction, reaching a minimum at the head of the Sound. The most important factors in controlling phytoplankton production and distribution in Howe Sound are strong light attenuation by the turbid Squamish River and flushing by the seaward-moving surface layer. Vernal peaks of phytoplankton production were observed at stations throughout the Sound prior to the Squamish River freshet, but production at up-inlet stations fell sharply with the commencement of freshet and remained low throughout the growing season.

The boundary area of Howe Sound is the region of highest phytoplankton production in the Sound due to a more favourable light and nutrient regime which results in continued production throughout the growing season. Nitrate (a nutrient) levels in the euphotic zone fell below detectable levels at most stations in the Sound just preceding the peak of the vernal phytoplankton bloom and remained low until complete mixing in November-December. High nutrient levels were maintained in boundary waters during the summer by entrainment and mixing in the surface layer resulting from open exposure to winds (Stockner et al., 1977).

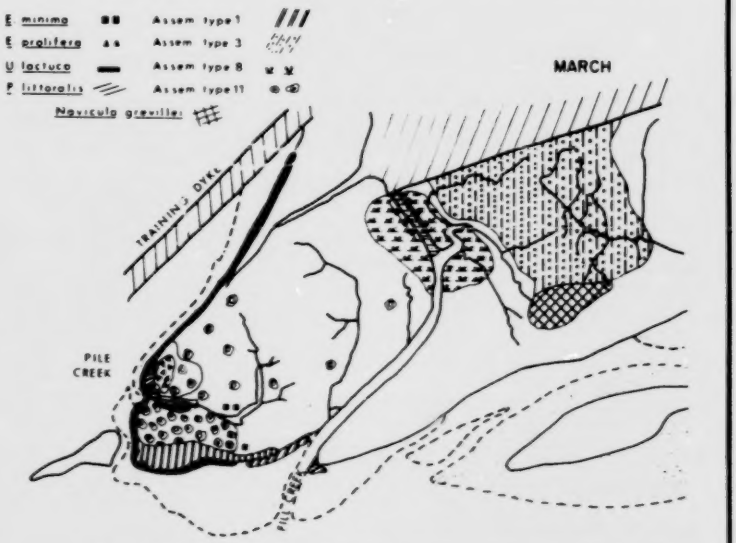
The dominant plankton species in Howe Sound were all diatoms Skeletonema costatum, Thalassoisira aestivalis, T. nordenskioldii, T. pacifica, and Chaetoceros spp., with S. costatum and T. pacifica dominant at all stations. Freshwater species observed at the head of the Sound included Asterionella formosa, Hannaea arcus, Meridion circulare, Eunotia sp., Stauroneis sp., and Tubellaria flocculosa (Stockner et al., 1977). Pomeroy and Stockner (1972) noted that benthic diatoms originating on the Squamish River delta were common in phytoplankton at the head of Howe Sound.

Benthic algal species diversity and annual net productivity on the Squamish River delta were greatest east of the training dyke because of a more stable, higher salinity habitat than on the West delta, which receives virtually all the Squamish River runoff (Pomeroy and Stockner, 1976). Strongly euryhaline species (tolerating wide ranges of salinity) such as the chlorophytes Enteromorpha minima, Ulva lactuca, and Rhizoclonium riparium were widely distributed on the delta. Weakly euryhaline algae were mainly located east of the training dyke with Enteromorpha prolifera and Pylaiella littoralis confined to this area. Pomeroy and Stockner (1976) suggested that weakly euryhaline species were unable to colonize the delta prior to training wall construction in 1972. The intrusion of Fucus vesiculosus, a marine phaeophyte into the Central basin during the study period from 1972 to 1973 supports the above statement.

Pomeroy and Stockner (1976) reported that species diversity, distribution, and production of benthic algae on the Squamish delta are greatest in late winter and early spring (Figure 7). During this period increasing light intensity, loss of marsh vegetation, and higher salinity and lower sedimentation rates resulting from low river runoff contribute to optimal conditions for colonization and growth. Pomeroy (in prep.) determined that benthic algal production on the Central delta was greatest from November to March (254 to 473 kg C $mo.^{-1}$ and least from August to October (73 to 93 kg C $mo.^{-1}$). An algal association dominated by the chlorophyte Ulothrix flacca was responsible for greater than half of the benthic algal annual net



Distribution of benthic algae on the Central delta in September. Representative of summer–fall distribution patterns. (Dotted areas are mud flats exposed at low tide.)



Distribution of benthic algae on the Central delta in March. Representative of winter–spring distribution patterns. (Dotted areas are mud flats exposed at low tide.)

Figure 7. Squamish Estuary Benthic Algae Distribution (from Pomeroy and Stockner, 1976)

production. High production of this association was due to the large area of uniform substrate made available for colonization by the death of the sedge Carex sp. (a vascular marsh plant), in October.

Pomeroy (in prep.) was concerned primarily with the manner in which benthic algae contribute energy to the ecosystem. He determined that though benthic algae store little energy compared to Carex sp., algae are immediately available as a food source and provide cover material at low tide for benthic invertebrates. Furthermore, organic removal data indicated that benthic algae provide a constant source of organic material.

2.3.3 Intertidal Brackish Marshes

Lim and Levings (1973) conducted a detailed survey of marsh communities in the Squamish River estuary. Twenty-four species of plants and ten vegetation divisions were identified and mapped (Tables II, III, and IV, and Figures 8, 9, and 10). Members of the sedge family were the dominant plants of the estuary. Carex lyngbyei (Lyngbye's sedge) was the most widespread species and contributed the greatest standing crop. The areas covered by marsh vegetation on the West, Central, and East deltas were 94,000 m^2, 182,000 m^2, and 107,325 m^2, respectively.

Further studies by Levings and Moody (1976) indicated that net above ground production of Carex sp. on the Central and East deltas at Squamish (1,322 g dry wt. m^{-2} $season^{-1}$) was among the highest reported in the literature. There were significant differences in mean standing crop values (dry weight) in July and August 1974 between deltas; 698 g m^{-2} on the Mamquam delta, 1,259 g m^{-2} on the East delta, 1,016 g m^{-2} on the Central delta, and 899 g m^{-2} on the West delta. Lower density of sedge stands on the West delta was responsible for the lower standing crop. On the Mamquam delta density of sedge stands was similar to that on the East and Central deltas, however, individual plants were less robust and shorter. Levings and Moody (1976) suggested that higher salinity values on the Mamquam delta were responsible for the less robust sedge form.

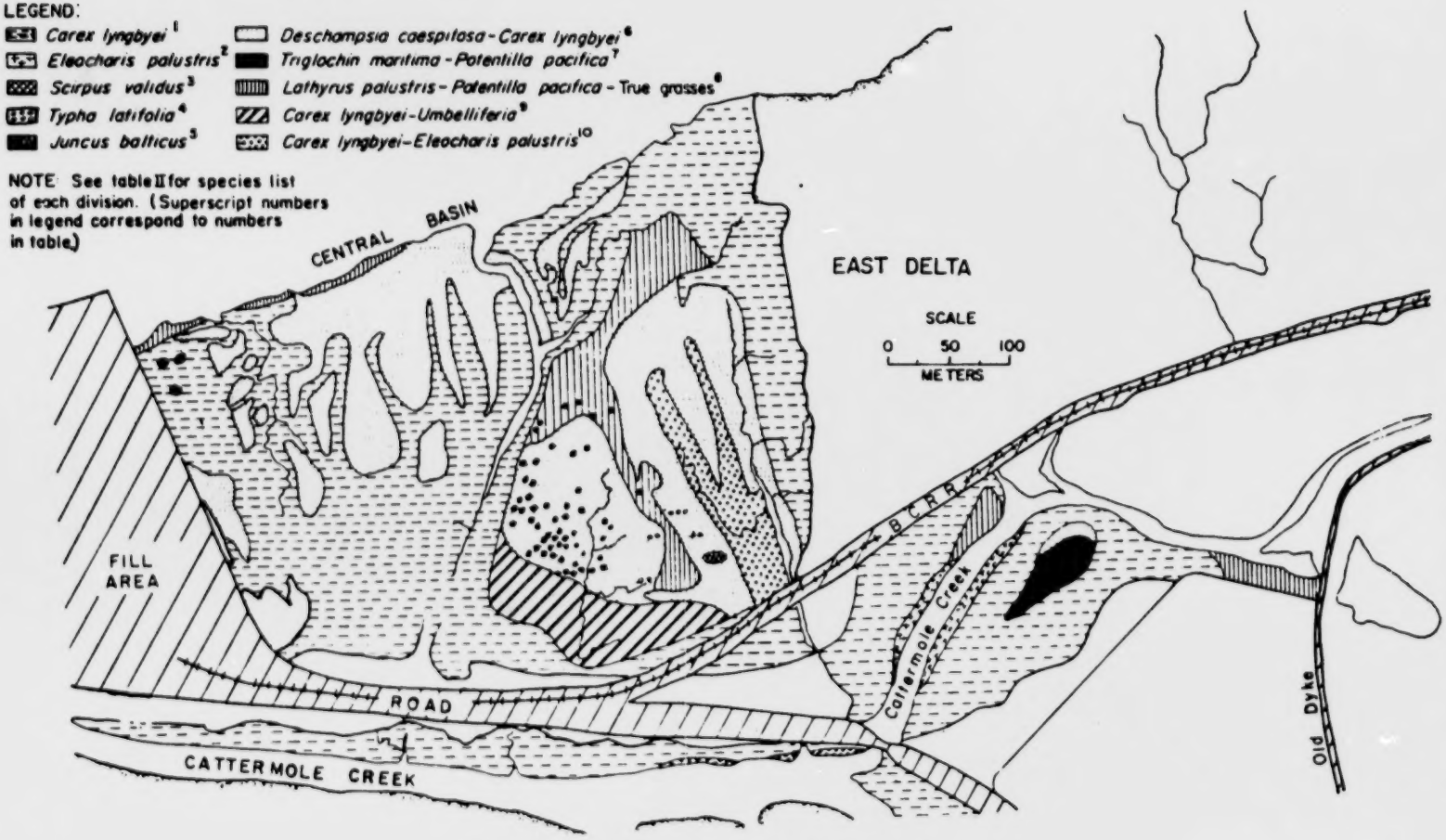


Figure 8. Distribution of Vegetation on the East Delta (from Lim and Levings, 1973)

TABLE II: DIVISIONS OF VEGETATION ON THE EAST DELTA (FROM LIM AND LEVINGS, 1973)

DIVISION	VEGETATION
1	*Carex lyngbyei*
2	*Eleocharis palustris*
3	*Scirpus validus*
4	*Typha latifolia*
5	*Juncus balticus* *Potentilla pacifica* *Triglochin maritima* *Carex lyngbyei* *Eleocharis palustris* *Trifolium wormskjoldii*
6	*Deschamsia caespitosa* *Carex lyngbyei* *Potentilla pacifica* *Plantago maritima* *Sium suave* *Triglochin maritima* *Juncus balticus* *Eleocharis palustris* *Lathyrus palustris*
7	*Triglochin maritima* *Potentilla pacifica* *Carex lyngbyei* *Sium suave* *Deschampsia caespitosa* *Plantago maritima*
8	*Lathyrus palustris* *Potentilla pacifica* *Aster eatonii* *Trifolium wormskjoldii* *Hordeum brachyantherum* *Agropyron repens* *Festuca rubra* *Deschampsia caespitosa* *Phalaris arundinacea* *Juncus balticus* *Plantago maitima* *Sium suave* *Cicuta maculata* *Sonchus arvensis* *Caltha aserifolia*
9	*Carex lyngbyei* *Sium suave*
10	*Carex lyngbyei* *Eleocharis palustris* *Triglochin maritima*

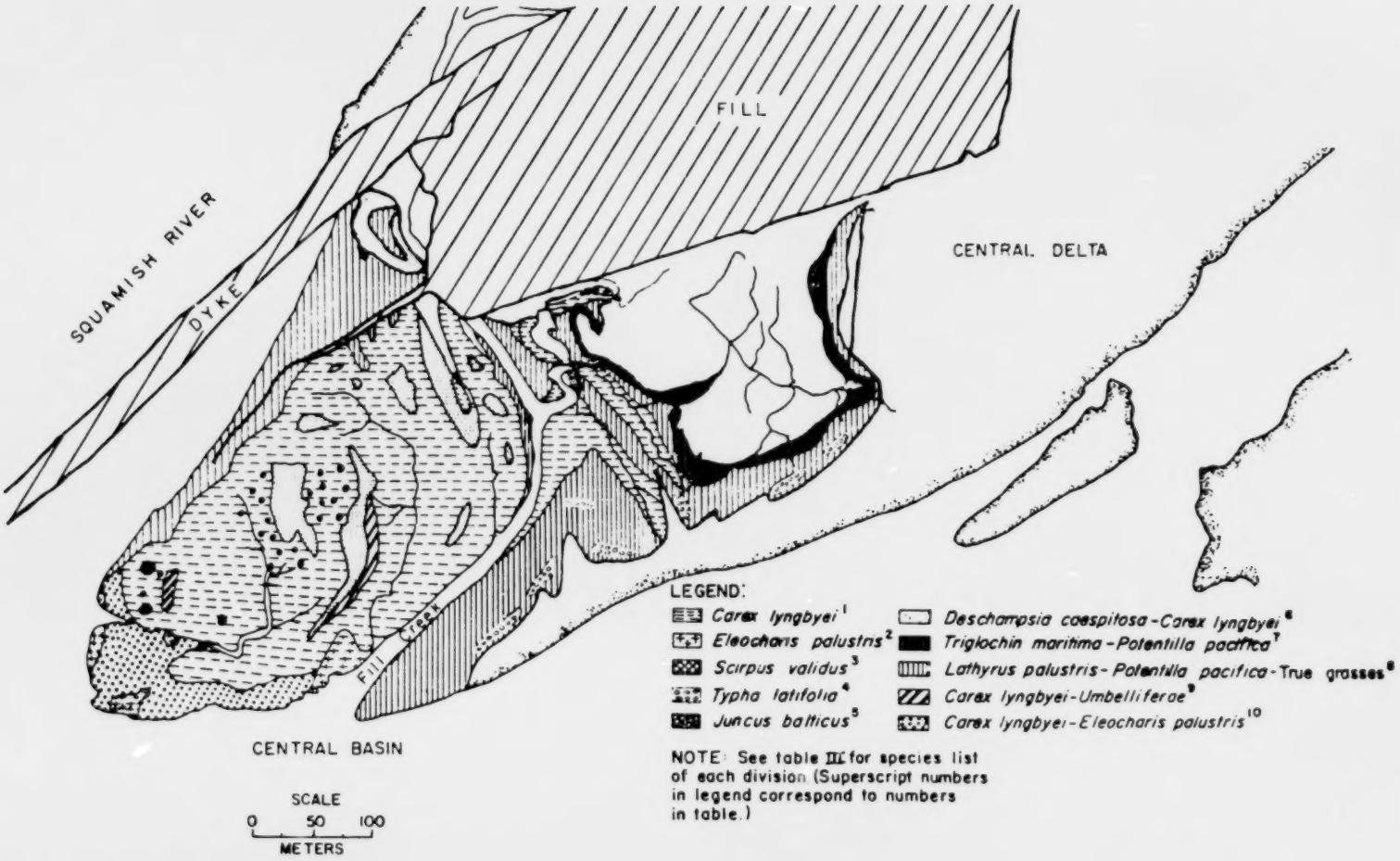

FILL
SQUAMISH RIVER
DYKE
CENTRAL DELTA
CENTRAL BASIN
SCALE
0 50 100
METERS
LEGEND:
Carex lyngbyei [1]
Eleocharis palustris [2]
Scirpus validus [3]
Typha latifolia [4]
Juncus balticus [5]
Deschampsia caespitosa - Carex lyngbyei [6]
Triglochin maritima - Potentilla pacifica [7]
Lathyrus palustris - Potentilla pacifica - True grasses [8]
Carex lyngbyei - Umbelliferae [9]
Carex lyngbyei - Eleocharis palustris [10]
NOTE: See table III for species list of each division (Superscript numbers in legend correspond to numbers in table.)

Figure 9. Distribution of Vegetation on the Central Delta (from Lim and Levings, 1973)

TABLE III: DIVISIONS OF VEGETATION ON THE CENTRAL DELTA (FROM LIM AND LEVINGS, 1973)

DIVISION	VEGETATION
1	*Carex lyngbyei*
2	*Eleocharis palustris*
4	*Typha latifolia*
6	*Deschampsia caespitosa* *Carex lyngbyei* *Potentilla pacifica* *Plantago maritima*
7	*Triglochin maritima* *Potentilla pacifica* *Carex lyngbyei* *Deschampsia caespitosa*
8	*Lathyrus palustris* *Potentilla pacifica* *Aster eatonii* *Hordeum brachyantherum* *Deschampsia caespitosa* *Festuca rubra* *Sidalcea hendersonii* *Sium suave* *Cicuta maculata* *Daucus carota* *Juncus balticus* *Maianthemum dilatatum* *Habenaria delatata* *Agropyron repens* *Plantago maritima* *Triglochin maritima* *Carex lyngbyei* *Eleocharis palustris*
9	*Carex lyngbyei* *Sium suave* *Cicuta maculata*
10	*Carex lyngbyei* *Eleocharis palustris*

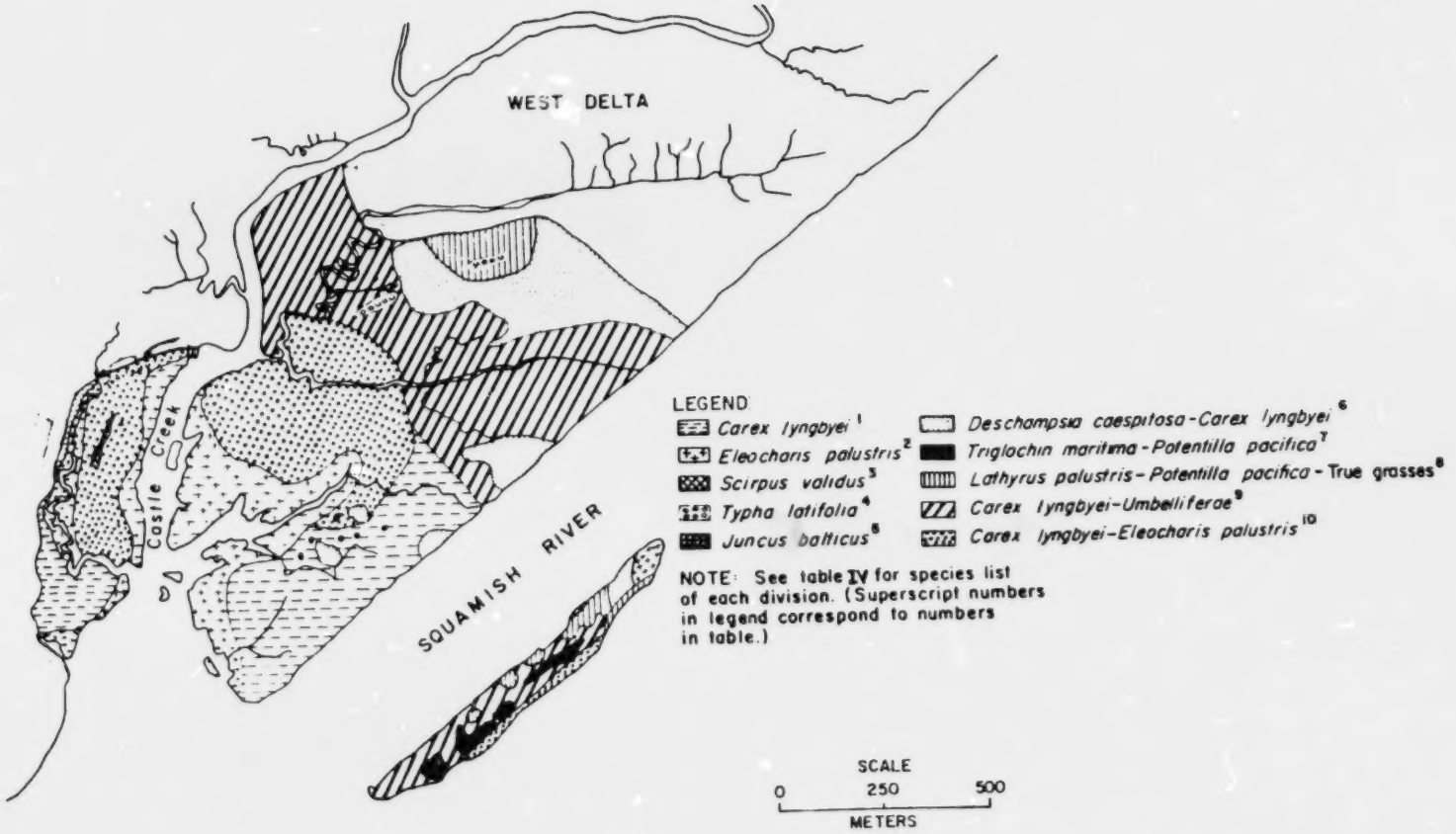


Figure 10. Distribution of Vegetation on the West Delta (from Lim and Levings, 1973)

TABLE IV: DIVISIONS OF VEGETATION ON THE WEST DELTA (FROM LIM AND LEVINGS, 1973)

DIVISION	VEGETATION
1	*Carex lyngbyei*
2	*Eleocharis palustris*
3	*Scirpus validus*
4	*Typha latifolia*
6	*Deschampsie caespitosa* *Carex lyngbyei* *Potentilla pacifica* *Triglochin maritima* *Sium suave* *Daucus carota* *Juncus balticus*
7	*Triglochin maritima* *Carex lyngbyei* *Potentilla pacifica* *Eleocharis palustris* *Juncus balticus*
8	*Lathyrus palustris* *Potentilla pacifica* *Trifolium wormskjoldii* *Sium suave* *Daucus carota* *Cicuta maculata* *Aster eatonii* *Sidalcea hendersonii* *Maianthemum dilatatum* *Plantago maritima* *Carex lyngbyei* *Juncus balticus*
9	*Carex lyngbyei* *Cicuta maculata* *Sium suave*
10	*Carex lyngbyei* *Eleocharis palustris* *Triglochin maritima*

Comparison of the distribution and composition of marsh communities in 1979 with that reported by Lim and Levings (1973) for 1972 indicated that changes in salinity regimes on the delta resulting from training wall construction had not resulted in changes in marsh vegetation in the Central and East deltas (Levings, 1980a).

2.3.4 Terrestrial Vegetation

The Squamish estuary study area is located in the southern portion of the Coastal Western Hemlock zone. Detailed floristic and environmental descriptions of the area have been presented by Orloci (1961 and 1964) and upland vegetation in the immediate vicinity of the estuary has been mapped by Howard Paish and Associates Limited (1972). Howard Paish and Associates Limited (1972) noted that vegetation types could be associated with elevation above high water (4.6 m above low tide) as follows, reed grasses predominated below 0.3 m, deciduous shrub thickets from 0.3 to 0.6 m, the Sitka spruce/cottonwood association from 0.6 to 1.5 m, and the Sitka spruce/broadleaf maple association from 1.5 to 4.6 m. On the slopes near the Stawamus River mouth a hemlock/cedar association was found.

2.3.5 Primary Productivity

Primary productivity is the rate at which energy is fixed, or organic matter created, by plants. Pomeroy (in prep.) has studied the relative contribution of benthic algae and vascular marsh plants (Carex sp.) to energy input and storage at the Squamish River estuary. Approximately 96 percent of the annual net primary productivity on the delta was attributed to Carex sp. while benthic algae were responsible for only about 4 percent.

Since plant material produced by Carex sp. must be changed by decomposition into detritus before it is generally available to consumers, Pomeroy (in prep.) suggested that benthic algae, though responsible for a relatively small amount of primary production, are important to the function of the estuarine system as they:

1. are readily available for consumption,

2. supply energy for specialized consumers,

3. are a possible requirement in the diet of some invertebrates,

4. are an auxiliary source of detritus when the breakdown of Carex sp. is lowest,

5. utilize nutrients regenerated from sediments and detritus.

From studies of energy conversion and storage, organic removal, grazing and detrital feeding, and incorporation of organic material into the sediments, Pomeroy (in prep.) proposed energy flow pathways for the Squamish River delta. Of energy stored by Carex sp., an estimated 90 percent is decomposed into particulate organic material (detritus), 4 percent becomes dissolved organic material which contributes to the heterotrophic decomposition of plant material, 5 percent is consumed by grazers, and 1 percent is lost through abscission. Of energy fixed and stored by algae, approximately 49 percent is decomposed into detritus, 22 percent is consumed by grazers, 20 percent becomes dissolved organic material, and 9 percent is removed from the delta. The detritus "pool" resulting from the decomposition of plant material is partially consumed by detritivors in-situ (approx. 18 percent). Approximately 33 percent remains in the estuary due to sedimentation and is incorporated into the sediments. The remaining 49 percent is removed from the delta for use in the surrounding estuarine ecosystem.

In summary, the Squamish River estuary is a detritus-based removal system with most of the energy input and storage attributable to vascular plants of the tidal marshes.

2.3.6 Information Gaps

Benthic algae and marsh vegetation of the Mamquam delta have not been studied as fully as those of the other Squamish River delta areas. Howard Paish and Associates Limited (1972) reported that the highest productivity of benthic algae on the delta was measured in Mamquam Channel but no methods or literature sources were mentioned. Marsh vegetation on the Central and Mamquam deltas was incompletely mapped by Lim and Levings (1973) according to Kennedy (1978) and Levings and Moody (1976).

During studies of the vegetation community function on the delta (Pomeroy, in prep.), below ground energy flow and the fate of removed organic material were not considered in any detail.

2.4 Benthic Invertebrate Populations

Benthic invertebrate communities of the Squamish estuary study area have been studied since 1972 by Levings (1976 and 1980a) who associated changes in benthic communities with river diversion and industrial development. Because of the predominance of Eogammarus confervicolus (Amphipoda) in fish stomach samples (Goodman and Vroom, 1972), the biology and energetics of this species was studied in detail by Levings (1980b). In order to explain the scarcity of the barnacle Balanus glandula in the Squamish estuary, Wu and Levings (1979) determined factors affecting its colonization. During a survey of macroinvertebrates and solid pollutants in Howe Sound, McDaniel (1973) made observations of subtidal invertebrates inhabiting the Squamish River delta front.

2.4.1 Intertidal Benthic Invertebrates

Fifty-one taxa of intertidal benthic invertebrates were encountered on the Squamish River delta by Levings (1976 and 1980a), and Levings and McDaniel (1976). The most abundant taxa were the amphipods Corophium salmonis and Eogammarus confervicolus, the polychaetes Pygospio elegans and Manayunkia aestuarina, and dipteran insect larvae.

Ordination analysis of samples indicated that distribution and abundance of invertebrates was determined primarily by the salinity regime and distance from the river, and secondarily by elevation and substrate type (Levings, 1980a). Mean abundance of dominant taxa in quadrat samples from three major habitat types on five delta regions are presented in Table V. Freshwater and estuarine invertebrates such as dipteran insects and Eogammarus confervicolus were abundant in higher stations (mud/lower marsh and upper marsh) on the West and Central deltas. In areas subject to relatively high salinities, i.e. the Mamquam delta and lower stations at the front of the Central basin, estuarine and marine organisms, such as the polychaetes Pygospio elegans and Manayunkia aestuarina, were abundant.

Diversity and abundance of benthic invertebrates varied with habitat. The number of species per quadrat (0.25 m^2) ranged from less than five on the seaward portion of the West delta and the area of silt spillage on the Central delta to more than fifteen on the mudflats of the Mamquam delta. The number of individual organisms per quadrat was highest (5,000 to 50,000) in the lower portion of the Central delta and on the Mamquam delta mudflats, and lowest (less than 500) at habitats in the West delta in direct influence of the Squamish River and higher elevations in the area of silt spillage on the Central delta.

Levings (1976) observed that there were seasonal and spatial differences in the types of organisms collected in horizontal plankton tows on the delta (Figure 11). Presence of invertebrates in the plankton tows was related to river runoff. High current velocities (25 to 30 cm $sec.^{-1}$) near the river were responsible for larger concentrations of drift organisms, such as Eogammarus confervicolus, in this area. Marine plankton penetrated the Central basin and Mamquam Channel in winter when fresh water was not widespread.

TABLE V: MEAN ABUNDANCE (NUMBER 0.25 m^{-2}) OF DOMINANT TAXA IN QUADRAT SAMPLES FROM MAJOR INTERTIDAL HABITATS AT THE SQUAMISH ESTUARY

	SAND (0 to 2.4 m O.D.)	Mean Number	MUD/LOWER MARSH (2.5 to 3.6 m O.D.)	Mean Number	UPPER MARSH (3.7 to 5.0 m O.D.)	Mean Number
West	*Corophium salmonis*	368	*Corophium salmonis*	4159	Chironomid larvae A	559
	Oligochaeta	320	Chironomid larvae A	224	Oligochaeta	531
	Chironomid larvae A	120	*Eogammarus confervicolus*	176	Heleidae larvae A	400
			Gnorimosphaeroma oregonensis	101	Ostracoda	398
		(3/3)		(9/6)		(9/9)
Central Front	*Pygospio elegans*	4291	*Pygospio elegans*	7180	Heleidae larvae A	1172
	Harpacticoid copepods	1377	*Macoma balthica*	1151	Oligochaeta	890
	Oligochaeta	852	*Eogammarus confervicolus*	950	Halacarid mites	410
	Eogammarus confervicolus	206	Harpacticoid copepods	923	*Gnorimosphaeroma oregonensis*	220
	Macoma balthica	139	*Corophium salmonis*	99	Harpacticoids	86
		(12/8)		(13/9)		(11/11)
Central Upper	Heleidae larvae A	3417	Heleidae larvae A	1326		
	Corophium salmonis	2819	*Corophium salmonis*	344		
	Amphicteis	166	*Pygospio elegans*	287	Not applicable	
	Diptera larvae	105	Oligochaeta	203		
	Chironomid larvae A	102	Diptera M	42		
		(5/1)		(19/4)		
East	*Eogammarus confervicolus*	2169	Oligochaeta	1069	Heleidae larvae B	752
	Oligochaeta	289	*Eogammarus confervicolus*	857	Oligochaeta	560
	Heleidae larvae A	260	*Gnorimosphaeroma oregonensis*	792	Rhagionidae	144
	Corophium salmonis	243	Acari	253		
			Corophium salmonis	163		
		(3/2)		(8/7)		(1/1)
Mamquam	*Manayunkia eastuarina*	462	*Manayunkia aestuarina*	17386		
	Eogammarus confervicolus	295	*Pygospio elegans*	1449		
	Pygospio elegans	214	Oligochaeta	1001	Not applicable	
	Oligochaeta	109	*Eogammarus confervicolus*	682		
	Gnorimosphaeroma oregonensis	36	Harpacticoid copepods	291		
		(15/14)		(17/13)		

Bracketed numerals: Number of samples over which means were calculated/number of stations sampled.
(from Levings, 1980a)

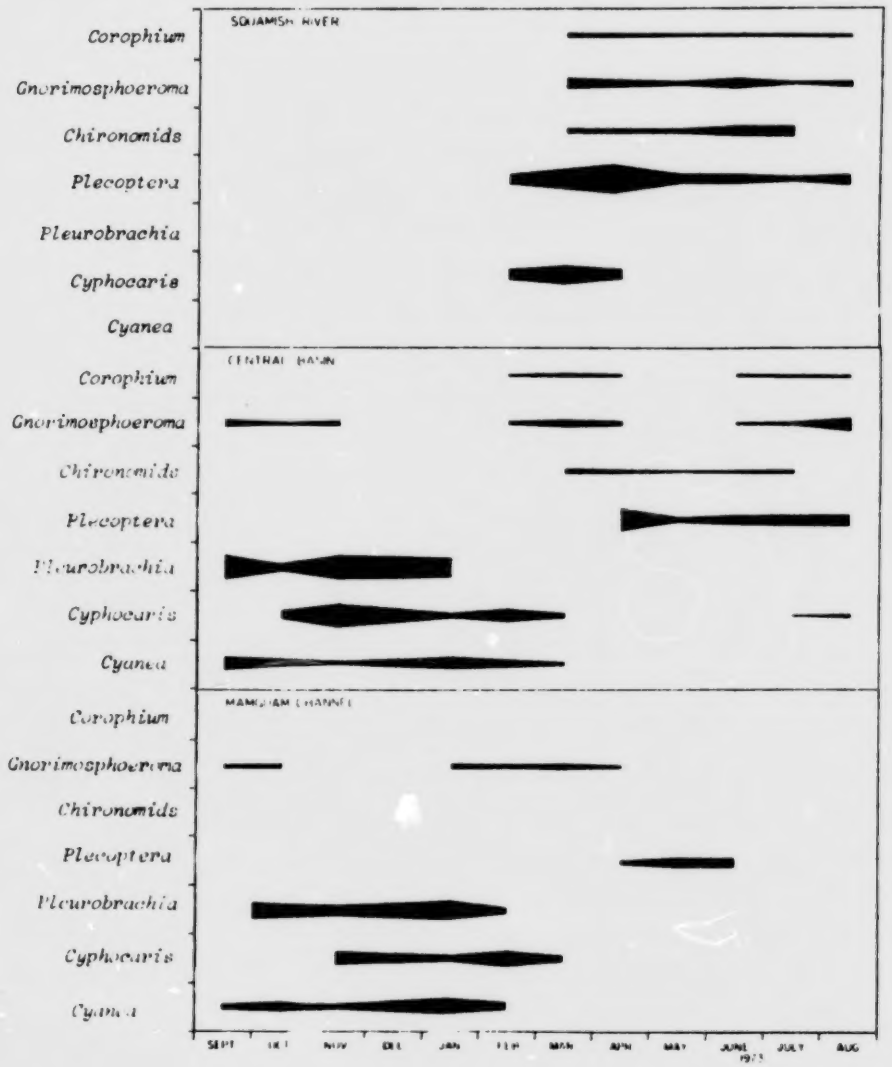


Figure 11. Seasonal Changes in Dominant Fauna from Horizontal Plankton Tows in the Squamish River, the Central Basin, and Mamquam Channel (from Levings, 1976) *Thickness of the horizontal bars is proportional to ranked abundance.*

Eogammarus confervicolus inhabiting the Squamish River delta has been studied in detail by Levings (1980b). These amphipods are most abundant under sedge rhizomes or algal material but are widespread over the delta. Their mean abundance was 524 m^{-2} in June, 1973 and 1,640 m^{-2} in April 1975. Under sedge rhizomes, there was an average of 7,360 m^{-2} in June 1973 and 13,960 m^{-2} in April, 1975. The dry weight biomass of amphipods under cover material differed significantly between deltas when averaged over a period of 12 months, 2.4 g m^{-2} on the West delta, 2.7 g m^{-2} on the East delta, 4.6 g m^{-2} on the Central delta, and 7.2 g m^{-2} on the Mamquam delta. The biomass of amphipods inhabiting a unit 300 m of shoreline for each delta was estimated at 510 g on the Central delta and 299 g on the East delta (based on a 37 cm wide belt of sedge rhizome cover material), 6480 g on the Mamquam delta (in a 3 m wide bank of Fucus sp.), and 2 g on the West delta where cover was discontinuous. Levings (1980b) suggested that construction of the training dyke reduced flushing of amphipods from the central area of the estuary and was responsible for the relatively high abundance in this area.

On the Central delta the abundance of amphipods under sedge rhizomes and benthic algal changed seasonally. From November to March, when the standing crop of benthic algae was greatest (Pomeroy, in prep.), amphipods were about equally abundant in the two habitats. In spring and summer, amphipods were far more numerous under sedge rhizomes (Levings, 1980b).

Laboratory experiments on net growth efficiency indicated that growth rates of amphipods are greatest on a diet of benthic algae under conditions simulating spring on the Central delta and summer on the Mamquam delta, and least under conditions simulating summer at the West delta. This data emphasizes the importance of the Central delta for invertebrate production (Levings, 1980b).

Wu and Levings (1979) transplanted a population of the barnacle Balanus glandula to the Squamish estuary and suggested that poor survival, fecundity, and growth were due to low, fluctuating

salinity and high turbidity. The turbidity at the estuary caused reduced production of phytoplankton which was required as food for the filter-feeding barnacles.

2.4.2 Subtidal Benthic Invertebrates

McDaniel (1973) observed subtidal invertebrates on the delta front at Squamish while conducting a survey of macroinvertebrates in Howe Sound. Off the West and Central deltas, the crab, Cancer magister, was very abundant. Other species observed were the shrimps Pandalus goniurus and P. danae; the nudibranch Hermissenda crassicornis; the crabs Chionoecetes sp., Cancer productus, and C. oregonensis; and the anenome Metridium sp.

2.4.3 Information Gaps

In light of the importance of sedge rhizomes as cover for invertebrates, Levings (1976) has suggested that the long term effects of the training wall on marshes of the central area of the estuary should be monitored. It is possible that the increase in salinity may have a detrimental effect on the brackish water species, Carex lyngbyei.

Levings (1980b) did not obtain information on generation time and longevity of Eogammarus confervicolus during his studies on the species. This information would be of value in examining how the species is exploited by juvenile salmonids.

Some habitats within the study area have not been studied in any detail with respect to benthic invertebrates. For instance, no information is available on freshwater invertebrates inhabiting the river channel between the culverts and the upper boundary of the study area and only preliminary observations have been made on subtidal invertebrates of the delta front (McDaniel, 1973).

2.5 Fisheries Resources

2.5.1 Salmon Fishery

The Squamish River system supports four species of Pacific salmon; chum (Oncorhynchus keta), chinook (O. tshawytscha), coho (O. kitsutch), and pink (O. gorbuscha).

2.5.1.1 Escapement

Records of chum, chinook, coho, and pink salmon escapements to the Squamish River have been made annually by the Department of Fisheries and Oceans since 1947 (Table VI). Escapements to the mainstem and principal tributaries during the 1968-1979 period are presented in Table VII.

The average annual chum escapement to the system dropped to 46,212 during the 1956-1967 period from the previous 58,563 average during the 1947-1955 period (Figure 12). The recent 1968-1979 average annual escapement of 111,454 chum represents a significant increase over the previous two periods. Average annual chinook escapement of 16,868 during the 1956-1967 period represents a slight increase over the 16,144 average recorded for the 1947-1955 period; however, the most recent (1968-1979) average of 10,505 is significantly reduced from previously recorded levels.

Average coho escapement to the river system has dropped to 33,516 during the 1956-1967 period from the previous average of 47,561 during the 1947-1955 period but has recovered slightly to an average of 36,114 during the recent 1968-1979 period.

Pink escapement has declined steadily since 1947 but most drastically during the most recent 12 year period. The 1947-1955 annual average (odd years only) of 252,700 declined to 249,883 during the 1956-1967 period and dropped dramatically to 40,020 per year during the 1968-1979 period.

Escapement figures may vary from year to year simply due to changing stream conditions, accessibility, and recording methods of personnel. However in the Squamish River area, stream accessibility and recording personnel have remained relatively unchanged for a

TABLE VI: ESTIMATED TOTAL SALMON ESCAPEMENT TO THE SQUAMISH SYSTEM (1947-79).

	Chinook	Coho	Pink	Chum
1947	15,625	4,525	434,000	31,325
48	15,500	78,050	-	80,750
49	15,500	23,550	294,000	40,400
50	15,625	20,425	-	42,400
51	15,975	91,600	224,000	53,575
52	15,500	702,000	-	201,000
53	18,900	20,675	195,000	19,650
54	16,700	53,275	-	23,900
55	15,975	33,950	116,500	26,075
56	15,550	18,475	-	12,700
57	19,100	55,150	111,575	74,250
58	18,900	35,200	-	71,900
59	17,100	20,350	157,025	157,000
60	15,550	25,775	-	26,075
61	19,100	59,200	384,200	21,050
62	18,900	23,350	-	50,475
63	9,100	16,525	732,000	40,900
64	7,575	55,750	-	33,900
65	35,750	46,350	75,500	7,300
66	18,900	24,175	-	18,300
67	6,900	21,900	39,000	40,700
68	10,600	23,700	-	103,200
69	24,800	30,850	24,500	48,700
70	31,000	55,700	-	100,400
71	11,235	47,400	24,100	22,975
72	9,450	16,150	-	307,200
73	13,850	38,300	138,000	225,000
74	9,250	107,500	-	153,000
75	4,025	58,150	43,575	51,900
76	4,900	10,400	-	112,000
77	4,060	13,000	3,095	112,325
78	1,540	15,775	-	70,100
79	1,550	16,450	6,850	30,650

TABLE VII: ESTIMATED SALMON ESCAPEMENTS TO THE SQUAMISH SYSTEM. (1968-79 INCLUSIVE)

		Chinook	Coho	Pink	Chum
Squamish River	1979	1,000	7,500	3,000	15,000
	78	1,000	7,000	-	20,000
	77	3,500	7,500	1,500	35,000
	76	3,500	3,500	-	75,000
	75	3,500	35,000	35,000	35,000
	74	7,500	75,000	-	70,000
	73	2,000	18,000	70,000	120,000
	72	8,000	4,500	750	200,000
	71	8,000	18,000	15,000	15,000
	70	25,000	15,000	-	50,000
	69	20,000	8,000	10,000	18,000
	68	10,000	7,000	-	70,000
Cheakamus River	1979	200	200	400	8,000
	78	150	1,500	-	60,000
	77	200	1,500	750	75,000
	76	400	1,500	-	15,000
	75	200	15,000	3,500	7,500
	74	400	15,000	-	35,000
	73	300	4,000	25,000	50,000
	72	400	1,500	-	60,000
	71	2,200	4,500	2,200	4,500
	70	3,000	6,000	-	25,000
	69	2,000	2,000	12,000	20,000
	68	300	4,000	-	30,000
Mamquam River	1979	50	200	750	450
	78	60	400	-	30,000
	77	200	200	750	750
	76	400	750	200	15,000
	75	75	750	3,500	7,500
	74	400	3,000	-	25,000
	73	750	2,500	35,000	45,000
	72	350	1,500	-	45,000
	71	700	6,000	1,500	3,000
	70	1,500	8,000	-	25,000
	69	800	500	500	10,000
	68	100	500	-	2,500
Ashlu Creek	1979	250	150	50	50
	78	250	200	-	25
	77	150	150	75	75
	76	400	750	4,000	3,500
	75	200	3,500	1,500	1,500
	74	750	3,500	-	8,000
	73	600	600	5,500	7,500
	72	700	400	-	1,500
	71	300	700	5,000	400
	70	1,500	1,500	-	400
	69	2,000	300	2,000	700
	68	200	2,000	-	700
Shovelnose Creek	1979	50	100	50	150
	78	80	175	-	75
	77	10	150	20	1,500
	76	200	400	3,500	-
	75	75	400	400	75
	74	200	3,500	1,500	-
	73	200	1,200	2,500	2,500
	72	-	250	700	-
	71	35	200	75	400
	70	-	200	-	-
	69	-	50	-	-
	68	-	200	-	-

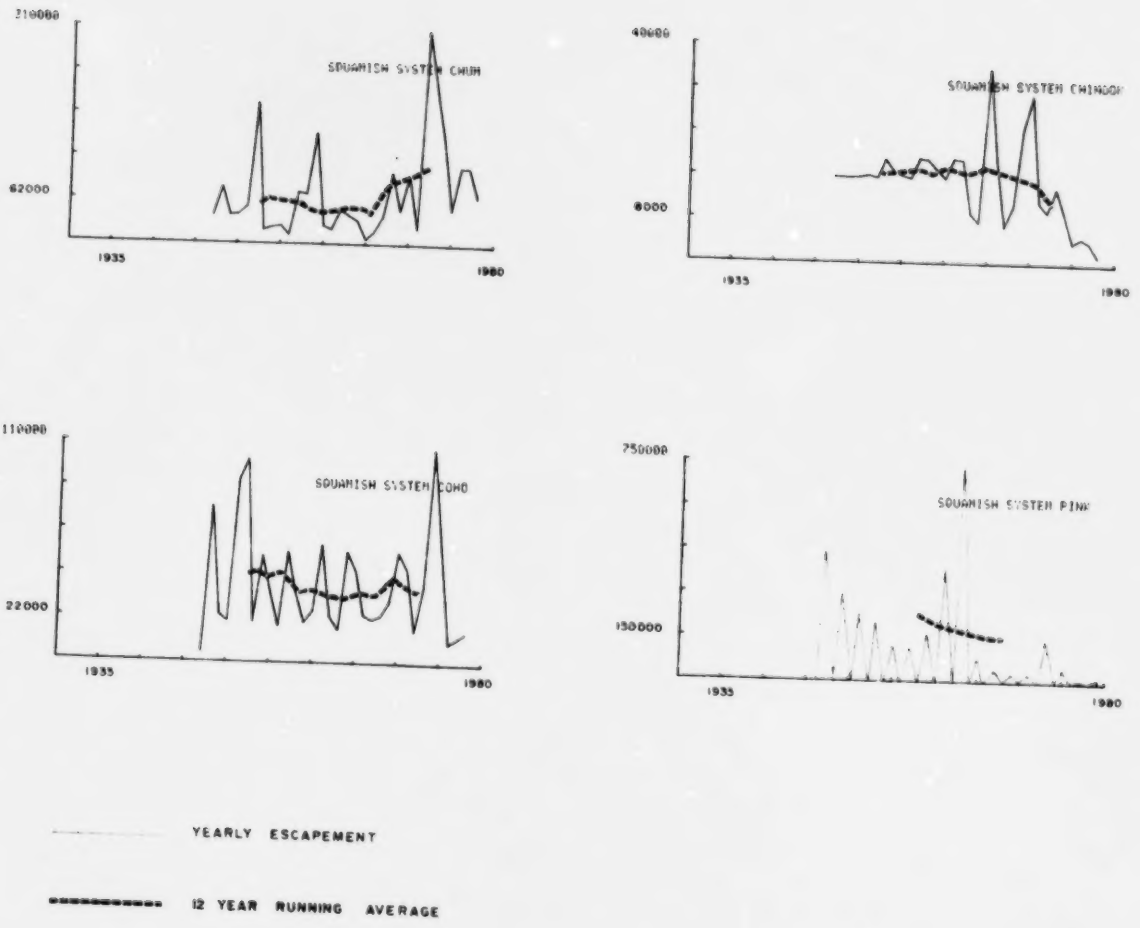


Figure 12. Squamish River System Salmon Escapements, by Year and 12-Year Running Average

number of years thereby increasing the reliability of the data. It should be noted that changing stream and water clarity conditions of the Squamish River often make it difficult to accurately estimate salmon escapement, particularly that of chinook and pink salmon.

2.5.1.2 Catch

For the Squamish River system, catch to escapement ratios of 5:1, 5:1, 1.3:1, and 0.8:1 for chinook, coho, pink, and chum salmon respectively are utilized in estimating total catch (Table VIII). The Department of Fisheries and Oceans has estimated that the present salmon resource of the Squamish River is 572,377 fish. Of this total, 198,093 spawners produce an annual commercial catch of 266,030, a saltwater sport catch of 104,369, and an Indian food fishery catch of 3,885 salmon (Table IX). This salmon resource represents an annual commercial "net value" of $2,297,935 and an annual sport "net value" of $2,368,395 (1978 prices based on average wholesale values by area of catch, net of processing, and harvesting costs, Tables IX and X). No estimates of value of the Indian food fishery or Squamish fish caught in American waters are given.

The Squamish River system also supports a popular freshwater sport fishery for coho salmon. Wheeler (pers. comm. 1980) believes that the number of coho caught by sports fishermen in the Squamish systems falls in the range of 800-1,000 fish per year.

2.5.2 Trout and Char Fishery

Rainbow and steelhead trout (Salmo gairdneri), coastal cutthroat trout (S. clarki), and Dolly Varden char (Salvelinus malma) are present in the Squamish River system. Both anadromous and resident forms occur.

In addition to coho, the Squamish River system supports a major sport fishery primarily centered on steelhead, but which also includes cutthroat trout and Dolly Varden char. Data on sea-run cutthroat and Dolly Varden is not available, but Clark (pers. comm. 1980) notes that these species also contribute to the sport fishery.

TABLE VIII: ESTIMATED ALLOCATON OF CATCH BY SPECIES - SQUAMISH RIVER SYSTEM

Fishery & Gear	%	Chinook Catch Escapement ratio 5.0	%	Coho Catch Escapement ratio 5.0	%	Pink Catch Escapement ratio 1.3	%	Chum Catch Escapement ratio 0.8
Alaska								
Troll	7	3,677	-	-	-	-	-	-
North Coast								
Net	-	-	-	-	-	-	-	-
Troll	8	4,202	-	-	-	-	-	-
Central Coast								
Net	2	1,050	-	-	-	-	-	-
Troll	5	2,626	5	9,029	-	-	-	-
N.W. Vancouver Island								
Troll	2	1,050	5	9,029	7	3,641	-	-
S.W. Vancouver Island								
Troll	4	2,102	7	12,639	5	2,601	-	-
Johnstone Strait								
Net	3	1,575	3	5,417	28	14,567	62	55,281
Troll	-	-	-	-	1	521	-	-
Georgia Strait								
Net	-	-	-	-	1	521	-	-
Troll	11	5,777	5	9,029	-	-	-	-
Indian	4	2,102	-	-	-	-	2	1,783
Sport	40	21,010	41	74,034	-	-	-	-
Fraser River								
Net	8	4,202	1	1,806	7	3,641	26	23,183
Sport	4	2,102	-	-	-	-	-	-
Juan de Fuca Strait								
Net	1	525	8	14,445	16	8,324	-	-
Washington/Oregon								
Net	-	-	12	21,668	34	17,689	10	8,916
Troll	1	525	9	16,251	1	521	-	-
Sport	-	-	4	7,223	-	-	-	-
TOTAL CATCH	100%	52,525	100%	180,570	100%	52,026	100%	89,163

Source: Salmonid Enhancement Program Production Model, Catch Allocation Matrix

TABLE IX: ALLOCATION AND VALUES OF SQUAMISH RIVER STOCKS BY SPECIES AND GEAR (1978 PRICES IN 1980 DOLLARS)

Fishery and Gear	Chinook %	Chinook Total Catch	Chinook $*	Chinook Net Value	Coho %	Coho Total Catch	Coho $*	Coho Net Value	Chum %	Chum Total Catch	Chum $*	Chum Net Value	Pink %	Pink Total Catch	Pink $*	Pink Net Value
Alaska																
Troll	7.0	3,677	0	0	-	-	-	-	-	-	-	-	-	-	-	-
Canadian																
Net	14.0	7,353	19.67	144,608	12.0	21,668	14.90	322,817	88.0	78,464	14.07	1,104,361	52.0	27,053	4.64	125,921
Troll	30.0	15,758	13.21	208,207	22.0	39,726	8.66	343,974	2.0	1,783	14.57	25,978	13.0	6,763	3.26	22,069
Indian	4.0	2,101	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Sport	44.0	23,111	24.38	563,446	41.0	74,034	24.38	1,804,949	-	-	-	-	-	-	-	-
Washington/ Oregon																
Net	-	-	-	-	12.0	21,668	0	0	10.0	8,916	0	0	34.0	17,689	0	0
Troll	1.0	525	0	0	9.0	16,251	0	0	-	-	-	-	1.0	521	0	0
Sport	-	-	-	-	4.0	7,223	0	0	-	-	-	-	-	-	-	-
TOTAL	100.0	52,525		916,261	100.0	180,570		2,471,740	100.0	89,163		1,130,339	100.0	52,026		147,990

Sport fishing values are based on the demand response model developed in "Evaluation of Incremental Recreational Benefits from Salmonid Enhancement", Appendix 6, The Economic Rationale to the Salmonid Enhancement Program 1977. It is estimated that there are 2.69 angler days per boat day from Mary Harrison, Resident Boating in Georgia Strait, 1979 Update, Small Craft Harbours Branch, Department of Fisheries and Oceans. Angler days are valued at $20.06 per day. This is an updated 1980$ value from Appendix 6 The Economic Rationale of Salmonid Enhancement Program 1977.

* Denotes average dollar value per fish.

TABLE X: ESTIMATED WHOLESALE VALUE OF COMMERCIAL CATCH BY SPECIES AND GEAR - SQUAMISH RIVER

	END USE					
	Canned	Fresh, Frozen or Other	Avg. Wholesale Price per Piece	Avg. Harvesting Cost per Piece	Avg. Processing Cost per Piece	Net Value Per Piece
Gear and Species	%	%				
Net						
Chinook	15	85	30.88	2.31	8.92	19.67
Coho	73	27	19.98	.77	4.32	14.91
Chum	27	73	21.73	1.18	6.48	14.07
Pink	100	0	7.25	.15	2.45	4.64
Troll						
Chinook	0	100	23.06	3.54	6.31	13.21
Coho	0	100	13.12	1.44	3.01	8.66
Chum	0	100	21.98	2.16	5.25	14.57
Pink	35	65	6.00	.50	2.24	3.26

Average wholesale, harvesting and processing costs are derived from "Estimation of Commercial Fishery Benefits and Associated Costs for the National Income Account", Appendix 2, The Economic Rationale for the Salmonid Enhancement Program, 1977 (Revised 1980).

The steelhead fishery in the Squamish system is considered to be one of the finest in the Lower Mainland area, and one of the better fisheries in the entire province. Over 6,000 angler days per year are expended on the system in the pursuit of steelhead trout (Fish and Wildlife Branch, 1980).

The Fish and Wildlife Branch (1980) has assessed adult steelhead return and the steelhead recreational fishery of the Squamish River system (Table XI). This assessment was derived from combined analysis of statistical harvest data, creel census data, and biophysical study.

The social and economic aspects of the Squamish River sport fishery assumes great importance when one considers the proximity of the fishery to the Greater Vancouver area, British Columbia's largest population centre. It is conceivable that alteration or loss of habitat in the Squamish estuary could have profound effects on the fish populations of the Squamish system and, in turn, on an important sport fishery.

2.5.3 Recreational Crab Fishery

Dungeness and rock crabs are sport caught over the north end of Howe Sound, particularly the area off the delta front (Wheeler, pers. comm. 1981). Further information regarding the harvest of crabs is not available.

2.5.4 Use of Habitat by Fish

Goodman and Vroom (1972) sampled fish in the Squamish estuary from April to August, 1972 and observed that the largest densities of juvenile salmonids were found in the Central basin. Kask and Parker (1972) seined fish off the delta front to estimate numbers, identify species present, and to investigate food habits.

TABLE XI: ESTIMATES OF AVERAGE ANNUAL RUN SIZE, HARVEST AND ESCAPEMENT OF STEELHEAD IN THE SQUAMISH RIVER SYSTEM

	Total(1) Run	Number(2) Killed	Number(2) Released	Total(3) Catch	Angler(2) Effort (Days)	Escapement(1) to Spawning Grounds
Squamish Mainstem	890	292	289	581	3,226	598
Cheakamus River	674	158	228	386	2,676	516
Mamquam River	284	32	28	60	360	252
Other Tributaries	95	5	4	9	81	90
Total	1,943	487	549	1,036	6,343	1,456

(1) Estimates from combined analysis of 5-year harvest data (1974-1979), creel census data, and biophysical study.

(2) Based on 5-year average of harvest analysis data (1974-1979). A reduction of 32.6 percent has been incorporated for correction of sample return bias.

(3) Sum of number killed and number released.

Levy and Levings (1978) undertook a comprehensive survey of the fish community of the Central basin from 1975 to 1978, and Levy (1978) collected information on the feeding ability of chum salmon in a tidal creek of the Squamish estuary.

2.5.4.1 Species Present and Periodicity

Levy and Levings (1978) divided the fish species they caught in the Central delta of the Squamish estuary into two groups; temporary, and permanent residents. Species are listed below in approximate order of abundance:

Permanent Residents

Staghorn sculpin	Leptocottus armatus
Starry flounder	Platichthys stellatus
Surf smelt	Hypomesus pretiosus
Cutthroat trout	Salmo clarki
Dolly Varden char	Salvelinus malma

Temporary Residents

Herring	Clupea harengus
Chum salmon	Oncorhynchus keta
Coho salmon	O. kisutch
Chinook salmon	O. tshawytscha
Spiny dogfish	Squalus acanthias
Snake prickleback	Lumpenus sagitta
Prickly sculpin	Cottus asper
Shiner perch	Cymatogaster aggregata
Threespine stickleback	Gasterosteus aculeatus
Pink salmon	O. gorbuscha
Eulachon	Thaleichthys pacificus
Sand lance	Ammodytes hexapterus

Staghorn sculpins, which were the numerically dominant species in the estuary, were most abundant from June to September. Prickly sculpins were captured at various times of the year and probably spawned in the estuary (two gravid females were caught on April 22, 1976). Shiner perch were seasonally abundant in September and October. Herring are present in the estuary, but spawning has not been noted since 1969 (Wheeler, pers. comm. 1980).

The mean number of juvenile chum, chinook, and coho caught in beach seine samples are shown in Figures 13, 14, and 15. Seasonal abundances were similar to those reported by Goodman and Vroom (1972). Numbers of chum fry peaked in late April and early June, chinook in early July, and coho smolts in early June and early July.

Rainbow trout occur in both resident and anadromous (steelhead) forms. Rainbow are spring spawners and all age classes can be found in the system throughout the year. Steelhead migrate upstream to spawn from December through July, with the majority of the run occurring from March to May, peaking in April. Following emergence from the gravel in the summer months, the fry rear from one to three years before migrating downstream to the sea. The downstream smolt migration occurs primarily from March to July with the peak occurring in April (Clark, pers. comm., 1980). Most steelhead return to their spawning stream for the first time in their third to sixth year (they spend from one to three years at sea).

Both anadromous and resident coastal cutthroat trout are present in the Squamish system. Resident cutthroat can be found in all age classes throughout the year. Cutthroat are generally spring spawners, with sea-run fish returning to the rivers in late fall and early winter. Anadromous cutthroat juveniles remain in fresh water for two to three years before migrating to the sea. The downstream migration often coincides with that of juvenile salmon (Scott and Crossman, 1973). Sea-run cutthroat trout usually remain within the influence of the river or go only a short distance to sea. They stay in and near estuaries, sometimes returning to fresh water to feed. Johnston and Mercer (1976) reviewed data on sea-run cutthroat and noted that studies have indicated that these fish stay at sea for varying lengths of time, but virtually all return to fresh water in the same year they migrated out.

Detailed information regarding Dolly Varden char in the Squamish system is limited, but both resident and sea-run forms are present. Dolly Varden are fall spawners. The upstream migration of sea-run fish generally coincides with that of salmon, i.e. from August

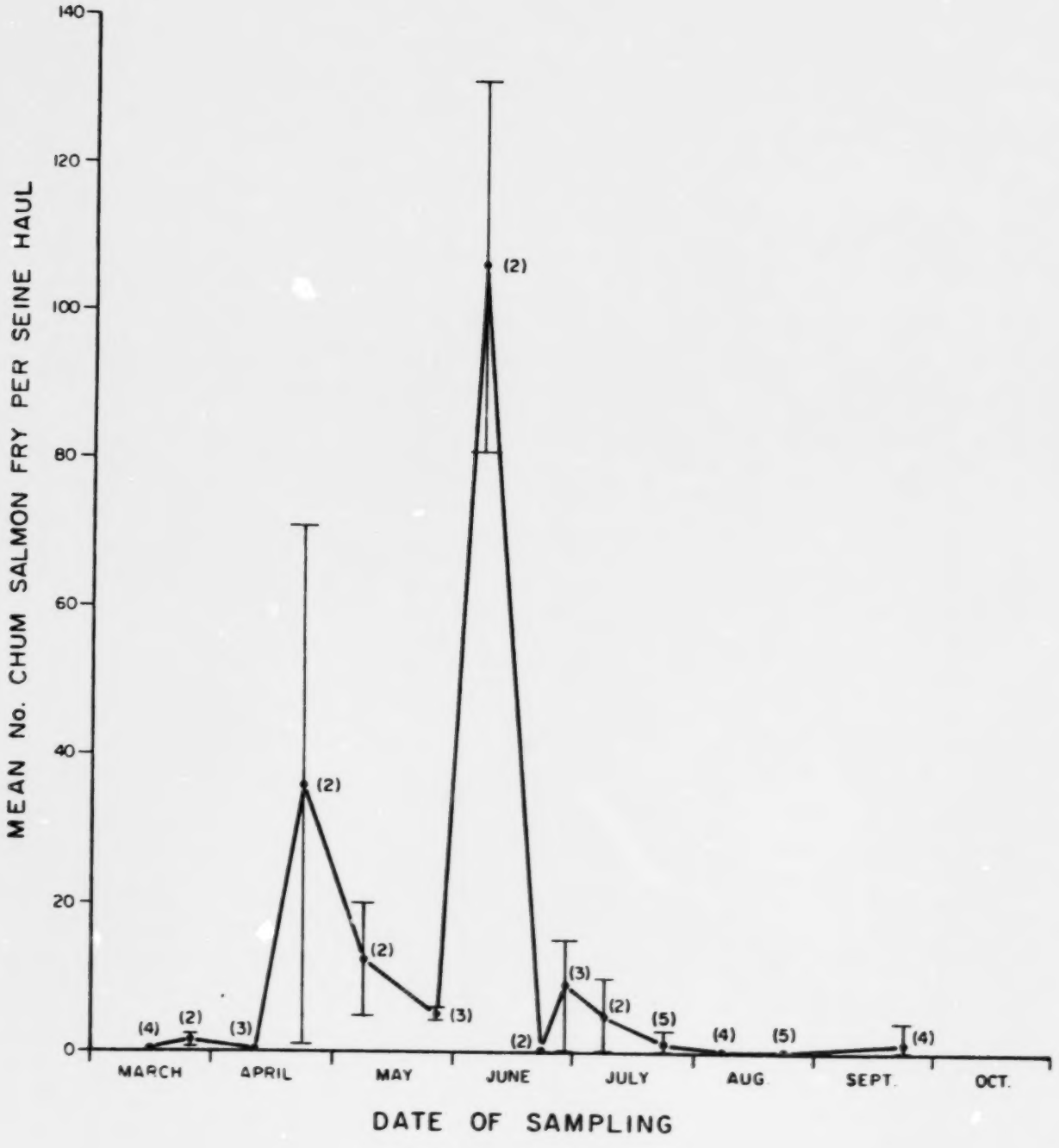


Figure 13. Number of Juvenile Chum Salmon per Beach Seine Haul at the Central Basin in the Squamish Estuary, 1976 (from Levy and Levings, 1976) *Mean and range, as well as the number of replicate seines (in brackets) are shown.*

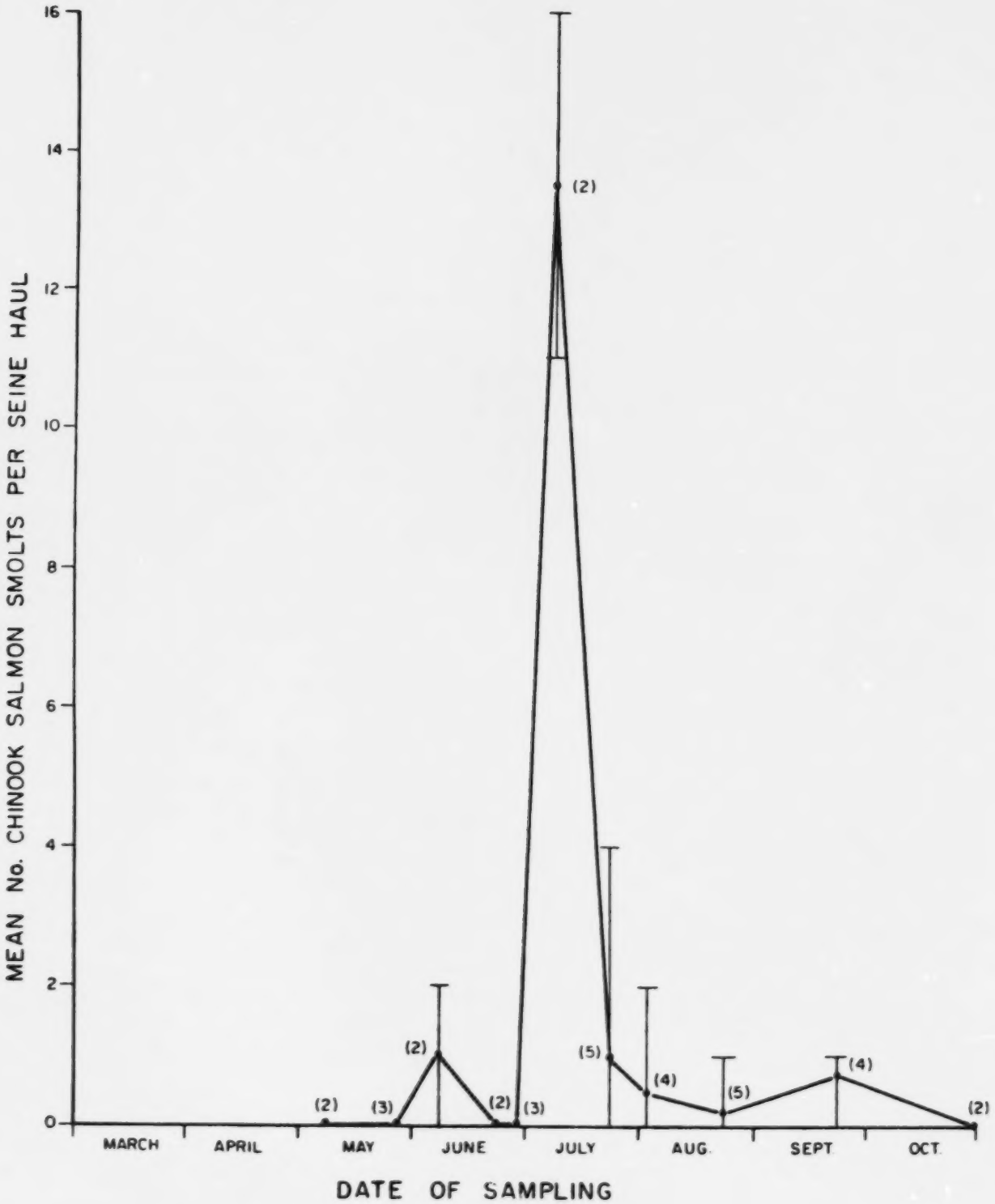


Figure 14. Number of Juvenile Chinook Salmon per Beach Seine Haul at the Central Basin in the Squamish Estuary, 1976 (from Levy and Levings, 1976) *Mean and range, as well as the number of replicate seines (in brackets) are shown.*

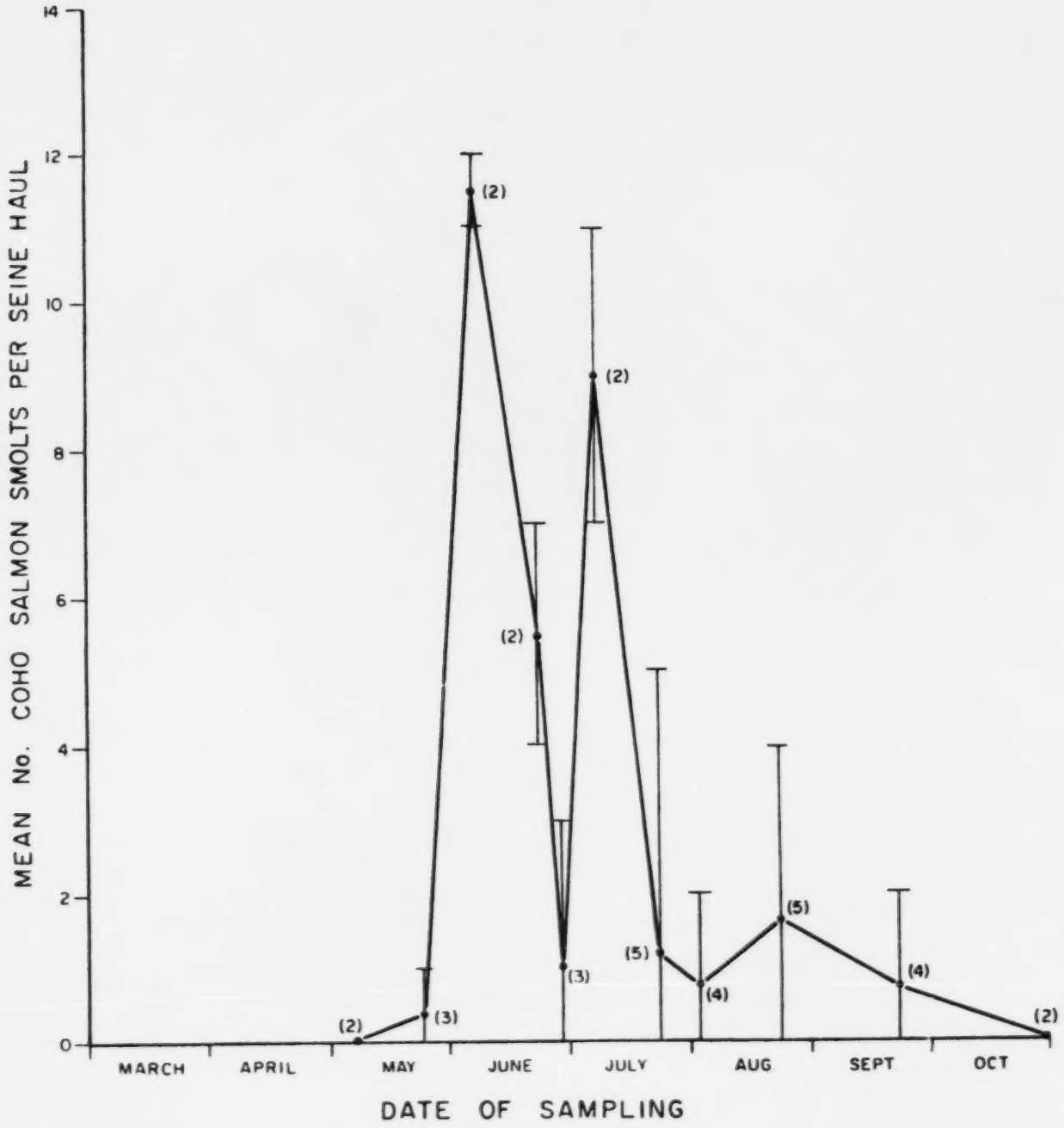


Figure 15. Number of Juvenile Coho Salmon per Beach Seine Haul at the Central Basin in the Squamish Estuary, 1976 (from Levy and Levings, 1976) *Mean and range, as well as the number of replicate seines (in brackets) are shown.*

to November (Clark, pers. comm., 1980). Following emergence in the spring, anadromous Dolly Varden fry spend 2 to 4 years in fresh water prior to migrating to the sea. Scott and Crossman (1973) note that Dolly Varden seaward migration generally occurs from May to June. They also noted that Dolly Varden spend anywhere from 60 to 160 days in the sea and that they usually tend to remain near river mouths or a short distance from them.

2.5.4.2 Distribution

The size of the catches taken by Goodman and Vroom (1972) indicated that the Central basin is the most favourable habitat for juvenile salmonids in the Squamish River estuary. Smallest catches of salmon were taken in the Mamquam Channel and on the east side of the Squamish Terminals' fill area. Ninety-nine percent of herring were caught on the east side of Squamish Terminals.

Levy and Levings (1978) correlated environmental factors with gillnet catches of fish with the following results:

1. Large gillnet mesh size, night set, and long set durations yielded high catches of staghorn sculpins.

2. High water temperatures, nearness to the mouth of the estuary, and a short set duration at night were associated with large catches of sculpins and pricklebacks, and low catches of cutthroat trout and surf smelts.

3. Clear water and location near the mouth of the estuary were associated with high dogfish catches.

4. Low salinity, small mesh size, and location near the head of the estuary were associated with high salmon smolt catch and surf smelt catch.

Reynolds (pers. comm. 1980) believes that cutthroat trout are present in the Central basin throughout the year. This species and Dolly Varden are thought to be the most abundant in May when chinook and pink salmon juveniles are in the estuary.

Although not substantiated by detailed study, it appears that most steelhead juveniles spend little time in the estuary prior to their departure to the sea. This assumption is based on scale analysis which showed marginal estuarine growth periods for Squamish River winter steelhead (Caverly, 1978). However, as part of a two year steelhead investigation of the Squamish River, Clark (1978) captured juvenile steelhead in the Squamish mainstem in October just north of the West delta. These fish were 3 year old pre-smolts. It could be expected that they would stay in the estuary area until the following April when they would migrate to sea. In both 1978 and 1979, Clark noted the presence of steelhead juveniles in Monmouth Creek, the only west-side tributary in the lower 20 miles of the Squamish River that supports a sizeable steelhead population.

Small numbers of steelhead, cutthroat, Dolly Varden, sculpin, stickleback, and lamprey were caught by Argue and Armstrong (1977) during a coho smolt tagging program in 1974 and 1975 on Meighn Creek, Tenderfoot Creek and the Little Stawamus River. Based on size, most of the trout were one year old, however, a few cutthroat spawners were captured as well. The authors noted that steelhead smolt migration peaked during or just before the last week in April.

Levings (pers. comm. 1981) captured two gravid cutthroat females in the Central basin about 1 km upstream of the training dyke culverts in January, 1981. Scale analysis of these specimens revealed that they were 5 and 4 years old and were of a sea-run race (Clark, pers. comm. 1981). Clark believes that the lack of a well-defined post-smolt winter check in the older fish is indicative of it having resided in a relatively stable environment since smolting; possibly within, or near, the estuary.

No population estimates are available for cutthroat and Dolly Varden in the Squamish system. Clark (1979) determined the average total run of steelhead in the Squamish River system to be approximately 2,000 fish per year (Table XI). This figure is based on recent creel census data, biophysical study, and statistical harvest analysis.

An estimate of the number of steelhead smolts migrating through the estuary can be obtained by back-calculating the smolt to adult survival ratio. The Salmonid Enhancement Program (1979) estimates an 8 percent smolt-to-adult survival for natural steelhead stocks. Based on the estimated return of 2,000 adults, the number of steelhead smolts migrating through the estuary each spring would be approximately 25,000 fish.

2.5.4.3 Diet

Food of several fish species inhabiting the Squamish estuary was examined by Goodman and Vroom (1972). Eogammarus confervicolus and Neomysis mercedis were the major food sources of juvenile salmonids, herring, sculpins, and starry flounders. Other estuarine benthic invertebrates and some insects also served as food for juvenile salmonids and herring.

Levy and Levings (1978) found the following taxa in varying proportions in the stomachs of salmonids captured in the Central basin:

Neomysis mercedis	- an estuarine opposum shrimp
terrestrial insects	
insect larvae	- mostly chironomids, occasionally dolichopodids and others
insect pupae	- mostly chironomids
copepods	- both cyclopoids and harpacticoids
unidentified fish	
Leptocottus armatus	- juvenile stages of staghorn sculpins
Eogammarus confervicolus	- an epibenthic estuarine amphipod
Corophium spinicorne	- a tube-dwelling estuarine amphipod
Gnorimosphaeroma oregonensis	- an estuarine isopod
Crangon sp.	- an estuarine shrimp

There was considerable variation in diet of juvenile chum salmon examined at monthly intervals from April to June, 1976. Insects were important on April 23, Eogammarus confervicolus and copepods made up the bulk of the diet of May 6, and Neomysis mercedis and terrestrial insects were the major prey items on June 27. Selection of the prey items E.confervicolus and N. mercedis by juvenile chum salmon was studied by Levy (1978) with the conclusion that the fish may be conditioned to select an abundant prey type.

Juvenile coho salmon fed largely on E. confervicolus and N. mercedis (Levy and Levings, 1978). The distribution of E. confervicolus at Squamish is associated strongly with the distribution of sedge. Coho juveniles seemed to respond to differences in density of prey type, feeding primarily on E. confervicolus at a station in the marsh and on N. mercedis at a station where sedge was absent.

The diet of juvenile chinook salmon consisted primarily of N. mercedis (Levy and Levings, 1978).

Dolly Varden char fed on E. confervicolus, N. mercedis, fish, and Crangon sp., in order of decreasing proportion of diet. Over 50 percent and 25 percent of the diet of cutthroat trout was made up of E. confervicolus and N. mercedis, respectively. There was a shift in the diet from N. mercedis in the summer to E. confervicolus in the fall and winter (Levy and Levings, 1978).

Kask and Parker (1972) sampled fish off the delta front and concluded that fish in the "outer" estuary utilized two food sources; marine plankton dependent on phytoplankton production, and an amphipod/insect complex dependent on algal and sedge production. From April to June there was a shift from the marine-based to the estuarine-based food source due to the decrease in phytoplankton production brought on by the freshet.

2.5.4.4 Growth Rates

Juvenile chum salmon in the estuary progressively increased in size from March to September, but chinook and coho did not show any

appreciable increase until July. Several hypotheses have been offered to account for the mid-summer depression in growth such as difference in residency time for early run and late run juveniles, limited food supply, or recruitment of smaller fish to the estuary (Levy and Levings, 1979).

Information pertaining to the growth rates of other species is not available.

2.5.4.5 Salmonid Spawning Areas

Locations within the study area that are used for spawning by salmonids are not well documented, although several sites have been identified (Clark, pers. comm. 1980; Wheeler, pers. comm. 1980). Chum salmon have been noted to spawn in a slough located on the west side of the Squamish River approximately 1.6 km upstream of the delta front. Pink spawning has been observed on gravel bars in the Squamish River about 0.7 km downstream of the Mamquam River. Monmouth Creek accommodates spawning chum and coho salmon, as well as steelhead trout. Coho and steelhead are known to spawn in Loggers Lane Creek (located at the head of Mamquam Channel), and these species are also suspected to spawn in a slough located near the high school. The Stawamus and Little Stawamus Rivers are used by spawning chum and coho salmon, and steelhead trout. Gravel patches located in the Central basin about 1 km upstream of the training dyke culverts may be used by spawning sea-run cutthroat trout (Levings, pers. comm. 1981; Clark, pers. comm. 1981).

Other spawning locations for these and other salmonid species may exist within the study area, but have not yet been identified.

2.5.5 Enhancement

The Fish and Wildlife (1980) and the Department of Fisheries and Oceans (1981) have compiled lists identifying past enhancement projects as well as those opportunities which exist for future enhancement.

In 1978 and 1979, habitat improvement of chum spawning grounds in Judd Slough (at Brackendale) and in Lower Paradise Channel (at Cheekye) has resulted in improved survival rates for this species. A barrier to fish passage in Brohm Creek was removed in 1979, providing access to upstream habitat for steelhead trout and coho salmon.

Steelhead stocks are currently being enhanced by a program of headwater stocking in Ashlu Creek. Approximately 80,000 steelhead fry are being released to barren upstream habitat each year. It is hoped that this program will result in a net increase of 600 fish/year to the Squamish steelhead fishery. A few small public involvement projects in the Squamish area are also underway which also contribute to the enhancement of fish stocks.

Further opportunities for salmonid enhancement in the Squamish system exist, but no detailed plans have been made in this regard. Consideration is being given to further steelhead fry introductions, as well as introductions of chinook salmon. There is a possibility of the construction of fish culture facilities for the enhancement of both salmon and trout stocks. A lake-pen rearing project is being considered, whereby steelhead fry would be raised to smolts and then released to the river. Further removal of barriers to fish migration is a possibility for increasing the amount of habitat available for fish production.

The feasibility of sea-run cutthroat trout enhancement is being considered, but no details are available at present. Enhancement of resident cutthroat, sea-run Dolly Varden, and resident Dolly Varden is not being considered at this time.

Ongoing refinement of fishery regulations and more stringent measures for habitat protection should serve to protect, and possibly enhance the fisheries resources of the Squamish River system.

2.5.6 Information Gaps

Many aspects of fish biology and habitat relationships at the Squamish estuary are poorly understood. Areas which should be further investigated are:

1. The inventory and biology of all fish species using the estuary.
2. The use of the estuary by steelhead trout, cutthroat trout, and Dolly Varden char, as well as use by Pacific salmon.
3. The relationships between habitat units and the fish species which use them.
4. The identification of possible impacts of environmental change in the estuary on salmonid populations.

2.6 Wildlife Resources

2.6.1 Terrestrial and Marine Mammals, Reptiles and Amphibians

Very little is known about the mammals, reptiles and amphibians that inhabit the Squamish River estuary and the adjacent uplands within the study area. Visiting and resident species are known, but abundance and habitat use patterns are not well understood. Incidental observations and known habitat preferences are the only sources of information. No systematic studies were done of the mammals, reptiles and amphibians that occur in the estuary.

2.6.1.1 Marine Mammals

Harbour seals (Phoca vitulina richardi), Pacific killer whale (Grampus rectipinna), harbour porpoise (Phocaena vomerina), and northern sea-lion (Eumetopias jubata) are probable visitors to the Howe Sound area (Environment Canada, 1973). Of these, Bigg (pers. comm. 1980) believes that harbour seals and killer whales are regular visitors to upper Howe Sound and the Squamish River estuary.

(a) Harbour Seals

Bigg (pers. comm. 1980) estimated that 20-30 harbour seals frequent the estuary and the main channel of the Squamish River. His personal observations since 1964 indicate that the largest populations of harbour seals occur in southern Howe Sound with natural haul-out sites at Pam Rocks near Anvil Island at at Popham Island. Defense Island (north of Anvil Island) is believed by Bigg to be the closest natural haul-out site to the Squamish estuary.

Land and Vaudry (1973) regularly observed harbour seals in the estuary from October 1972 to May 1973. The mean number observed was nine but up to sixteen were counted at one time.

Harbour seals are most abundant in the estuary during spring and early summer (March to June) when Pacific herring (Clupea harengus pallase) and eulachon (Thaleichthys pacificus) normally spawn (Bigg, pers. comm. 1980). Bigg noted that seal pupping occurs in late July and early August with nursing lasting about six weeks, during which the seals stay near the estuary. Bigg also reported that seals use log booms in the estuary as haul-outs.

(b) Killer Whales

Killer whales occasionally visit Howe Sound, apparently more for territorial reasons than for feeding (Bigg, pers. comm. 1980). Bigg believes that twenty whales are common, but up to sixty may visit the area, staying in deep water off the delta front.

2.6.1.2 Furbearers

At least eight species of furbearers occur in the study area. Land and Vaudry (1973) observed tracks of coyote (Canis latrans), river otter (Lutra canadensis), muskrat (Onadatra zebethica), red squirrel (Tamiasciurus hudsonicus) and raccoon (Procyon lotor) in the estuary. Harris (1972) reported signs of mink (Mustela vision) in the estuary. Forbes (pers. comm. 1980) believes that skunk, probably spotted (Spilogale gracilis latifrons), and bobcat (Lynx rufus fasciatus)

also use the study area. Many other species of furbearers, whose presence has not been confirmed by field studies, but which are believed to use the study area, are presented in a list compiled by Hoos and Vold (1975) from available literature.

Furbearers are likely to be distributed throughout the study area wherever there is suitable habitat. One indication of their use of the estuary is the existence of an active registered trapline (Clark, pers. comm. 1980).

2.6.1.3 Big Game Animals

Big game animals using the study area include Columbian blacktail deer (Odocoileus hemionus columbianus), black bear (Ursus americanus), and cougar (Felis concolor oregonensis) (Forbes, pers. comm. 1980). Reynolds (pers. comm. 1980) noted that the more isolated forested flats on the west side of the Squamish River and on the Mamquam flats provide year-round habitat for both deer and bear. He also noted that the adjacent mountain slopes support deer in summer. The Fish and Wildlife Branch (Peatt, 1979) identified the upper elevations of the mountains to the east and west of the Squamish estuary as general range for blacktail deer. Cougar, predators of deer, are found in similar habitat. Numbers of big game animals are presently undetermined (Forbes, pers. comm. 1980).

2.6.1.4 Non-game Animals

Hoos and Vold (1975) listed 34 non-game wildlife species in the Orders of shrews (Insectivora), bats (Chiroptera), rodents (Rodentia), and hares (Lagomorpha) that are believed to inhabit the study area.

Animals in the non-game group are probably distributed throughout the study area, but their abundance and habitat use in the estuary has not been studied.

2.6.1.5 Reptiles and Amphibians

Reptiles and amphibians in the estuary have not been carefully studied. The only available information is a list of nine species compiled by Hoos and Vold (1975).

2.6.2 Avian Resources

Species lists compiled by Hoos and Vold (1975) indicated that 187 species of birds potentially use the Squamish River estuary and adjacent water and upland areas. Canadian Wildlife Service (C.W.S.) surveys at the estuary during 1972-73 recorded nearly 43,000 individual bird sightings, or slightly more than 1,000 birds per visit, and 67 species during the migration and wintering periods (Table XII and Appendix A.1).

Because the turnover of birds during the migratory periods is unknown, it is not possible to determine the actual numbers of birds dependent on the estuary. However, by summing one-day maximum numbers of each species observed, it is possible to calculate a "best minimum estimate" of such dependence. Based on this methodology, it was estimated that at least 5,400 birds were dependent on the estuary October, 1972 to May, 1973 (Table XIII).

Such an estimate is conservative because it does not account for the daily turnover of migrating birds, nor does it reflect bird use for the whole year. It is suspected that far greater numbers of birds depend on the estuary throughout the year. This theory is substantiated by many of the species accounts which follow.

2.6.2.1 Waterbirds

Waterbirds include waterfowl (ducks, geese and swans) plus several groups of birds that usually obtain their food primarily from the water (e.g. gulls, loons, grebes, cormorants and alcids).

Waterbirds comprised approximately 88 percent of all birds counted October 1972 to May 1973 (Table XII). Of those, the most

TABLE XII: SUMMARY, BY BIRD GROUPS OF NUMBERS OF BIRDS SEEN IN EACH GROUP AND THE PERCENTAGE EACH REPRESENTS OF THE TOTAL NUMBER OF SIGHTINGS AT THE SQUAMISH RIVER ESTUARY OCTOBER 1972 TO MAY 1973

BIRD GROUP		NUMBERS OF BIRDS	PERCENTAGE OF TOTAL
WATERBIRDS			
Loons (2)*		226	0.5
Grebes (4)		12,170	28.4
Cormorants (2)		1,054	2.5
Swans (1)		75	0.2
Geese (1)		7	0.0
Ducks			
Dabblers (7)	5,867		13.7
Divers (12)	9,333		21.7
Total Ducks (19)		15,200	35.4
Gulls (3)		8,746	20.4
Alcids (2)		158	0.4
Coots (1)		1	0.0
TOTAL WATERBIRDS (37)		37,637	87.7
HERONS (2)		151	0.4
SHOREBIRDS (7)		374	0.9
BIRDS OF PREY (RAPTORS) (5)		191	0.4
SONGBIRDS (PASSERINES) (16)		4,516	10.5
OTHER BIRDS** (2)		47	0.1
TOTAL BIRDS (67)		42,196	100.00

* Numbers in parentheses represent numbers of species in each group seen.

** Includes Kingfishers (43) and Common Flickers (4).

TABLE XIII: ESTIMATED MINIMUM NUMBERS OF WINTERING AND MIGRATING BIRDS DEPENDENT ON THE SQUAMISH RIVER ESTUARY BASED ON OBSERVATIONS OCTOBER 1972 TO MAY 1973

BIRD GROUP		NUMBERS OF BIRDS	
WATERBIRDS			3,881
Loons		35	
Grebes		907	
Cormorants		141	
Swans		8	
Geese		7	
Ducks		1,631	
Dabblers	711		
Divers	920		
Total Ducks	1,631		
Gulls		1,118	
Alcids		33	
Coots		1	
TOTAL WATERBIRDS		3,881	
HERONS			13
SHOREBIRDS			153
BIRDS OF PREY (RAPTORS)			58
SONGBIRDS (PASSERINES)			1,311
OTHER BIRDS			5
TOTAL BIRDS			5,421

numerous sub-groups were waterfowl, grebes and gulls comprising 36 percent, 28 percent and 20 percent respectively of all birds seen and 96 percent of the waterbirds.

(a) Waterfowl

The C.W.S. surveys of 1972-73, the results of which are presented in following sections, indicate that the region is important as migratory or wintering habitat for waterfowl. Of the waterfowl, ducks were most numerous, comprising almost 99.5 percent of that group while geese and swans were seen in relatively insignificant numbers (Table XII).

i. Diving Ducks

Diving ducks, such as goldeneye, bufflehead and scaup, which typically obtain their food by diving (often to considerable depths), comprised 61 percent of the waterfowl, 25 percent of the waterbirds and 22 percent of all birds seen (Table XII).

Numbers of diving ducks which overwintered at the Squamish estuary began increasing in late October. Although individual daily counts ranged from less than 100 to more than 500, monthly mean numbers seen per day rose steadily to a peak of 378 in February 1973 (Figure 16, Appendix A.2). Total numbers of birds seen per day remained between 300 and 400 from February through April before declining markedly in mid-May. A final peak of 517 birds was seen April 18. By mid-May, most diving ducks apparently had left the estuary.

Approximately 99 percent of all diving ducks seen were: goldeneye (43 percent), bufflehead (27 percent), mergansers (20 percent) and scaup (9 percent) (Appendix A.1). Scoters, ruddy ducks, canvasbacks and oldsquaws were seen occasionally.

Goldeneye: Most goldeneye were seen on the lower Squamish River, while lesser numbers were seen in the Central basin and other channels and in the outer estuary. One flock of 150 common goldeneye was recorded from the outer estuary in early May. Daily counts of

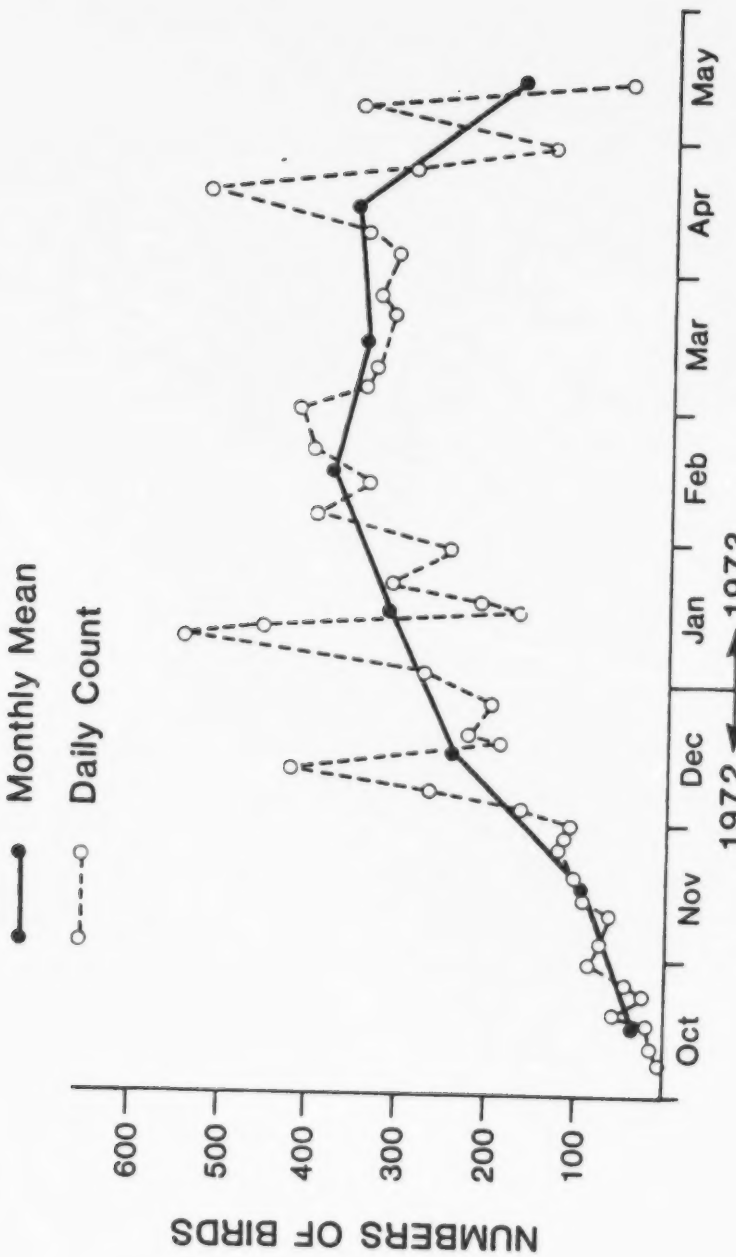


Figure 16. Numbers of Diving Ducks Seen at the Squamish River Estuary, October 1972 to May 1973

goldeneye fluctuated widely from zero to nearly 300, but monthly mean numbers of birds seen per day increased from two in October to 175 in February and then gradually decreased to approximately 55 at the study's termination in mid-May (Appendix B.1).

According to Munro (1939), both species of goldeneye rely heavily on invertebrate food items such as molluscs and crustaceans and to a lesser extent on marine algae. Munro also stated that if salmon eggs are available, goldeneye will eat them too, which may explain the apparent preference of goldeneye for the Squamish River especially during the fall and winter months. One would also expect to find invertebrate food items and marine algae throughout the rest of the intertidal and shallow subtidal portion of the estuary.

Bufflehead: Bufflehead were commonly seen in intertidal channels throughout the estuary, their numbers increasing October through April and then declining sharply by mid-May (Appendix B.2). Concentrations of bufflehead occasionally shifted location throughout the estuary. In October and November, and again February through May, most were seen in the Central basin whereas during December and January most were seen in the channels of the East delta.

Like their larger cousins the goldeneye, bufflehead feed primarily on aquatic invertebrates which they supplement with vegetation (Martin et al., 1951).

Mergansers: All three species of mergansers were seen in the estuary throughout the study, but common mergansers (60 percent) and red-breasted mergansers (20 percent) were most abundant (Appendix A.1). Hooded mergansers, never abundant (4 percent of all mergansers seen), were most numerous during spring and fall migration (Appendix A.1). Sixteen percent of the mergansers seen were not speciated.

Until December, relatively few mergansers were seen in the estuary (Appendix B.3). However, the addition of Mamquam Channel to the study area in December greatly increased the counts of common

mergansers, most of which (up to 225 birds per count) were seen at the mouth of the Stawamus River. Most red-breasted mergansers were seen in the outer estuary.

Munro and Clemens (1932, 1939) reported that in fresh water, both red-breasted and common mergansers fed extensively on salmon eggs when available. In salt water, they found that both species fed on small fish but red-breasted mergansers ate more herring whereas common mergansers apparently preferred sculpins and sticklebacks.

Stockman (1969) reported from 1,000 to 2,500 mergansers (presumably common mergansers) at the estuary during December 1968 and January 1969, evidently following the salmon migration. However, he did not report where in the estuary he observed those birds.

Scaup: Greater scaup first appeared regularly in December (Appendix B.4), and mainly used the channels of the East delta. In April, their numbers increased rapidly as spring migrants arrived. At that time, the birds left the East delta and were seen almost entirely on the Central basin.

Munro (1941) reported that, in British Columbia, the eggs of the Pacific herring are one of the most important seasonal foods of the greater scaup. Martin et al. (1951) reported that scaup also eat aquatic invertebrates and vegetation. Scaup are also known to congregate near sewage outfalls.

ii. Dabbling Ducks

Dabbling ducks, such as mallards, pintail and teal, which typically obtain their food by dabbling or "tipping-up"" in shallow water comprised almost 39 percent of the waterfowl, 16 percent of the waterbirds and 14 percent of all birds seen in the 1972-73 survey (Table XII).

Dabbling ducks were comprised of four main species: mallard (60 percent), pintail (23 percent), green-winged teal (9 percent) and American wigeon (5 percent) (Appendix A.1). Less often seen species included cinnamon teal, northern shoveler, and wood duck.

The fall migration of dabblers apparently reached its peak in late September or early October, but was nearly over by late October (Figure 17). A smaller but relatively constant population of dabblers remained through November until mid-December when a further drop in numbers occurred. Those dabblers remaining in January were joined by early spring migrants in February with numbers rising (with minor fluctuations) to a high of 516 in mid-April and then decreasing rapidly. By mid-May, the spring migration was almost over.

Dabbling ducks eat vegetation which they may supplement with some animal matter. Some dabblers, such as mallards, may opportunistically feed on foods of animal origin such as salmon eggs, rotting salmon flesh or molluscs. At the Squamish estuary, food plants for dabblers are readily available in the marshes and channels, and on mud flats where green algae may be obtained.

There were distinct areas which received the greatest use by dabblers (Figure 18, Appendix A.3 and Appendix B.5). Dabblers were occasionally seen feeding on exposed and relatively dry portions of the deltas, but generally fed in slightly flooded areas such as shallow channels, at the edges of the deltas at high tide or in depressions in the marsh at low tide. The birds often loafed and fed in the same locations and apparently preferred permanently or semi-permanently wetted areas.

In other large estuarine areas of southwestern British Columbia (for example, the Fraser River, Cowichan River, Nanaimo River, and Courtenay River estuaries) adjacent agricultural lands provide excellent supplementary feeding areas. However, because there is little agricultural land near Squamish, most dabblers must rely almost entirely on the estuary for food.

Eighty-six percent of all dabblers were seen in the three deltas (Appendix A.3). Of the total number of dabblers recorded in the deltas, approximately 49 percent, 20 percent and 31 percent were seen in the East delta, Central delta and West delta respectively

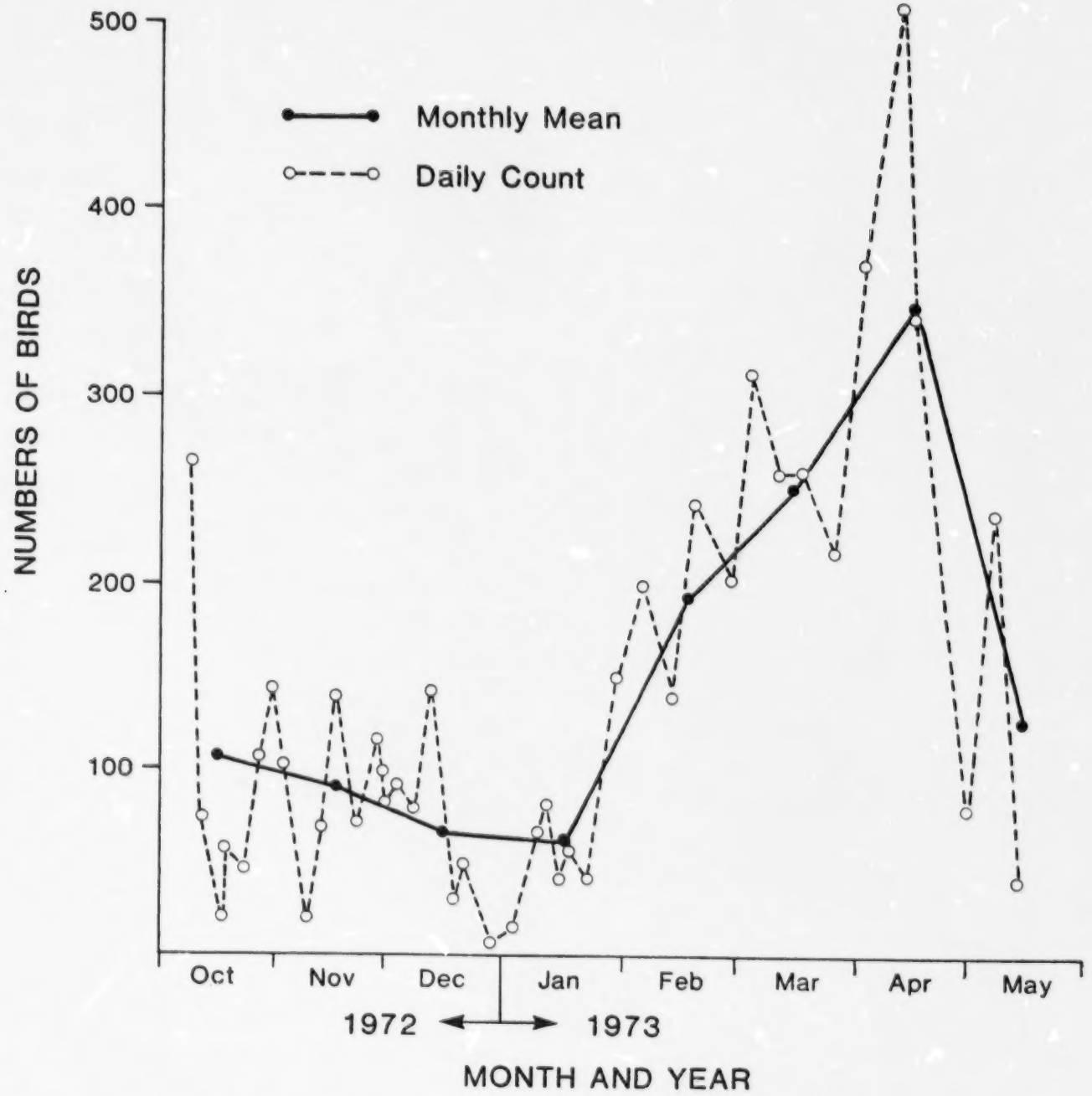


Figure 17. Numbers of Dabbling Ducks Seen at the Squamish River Estuary, October 1972 to May 1973

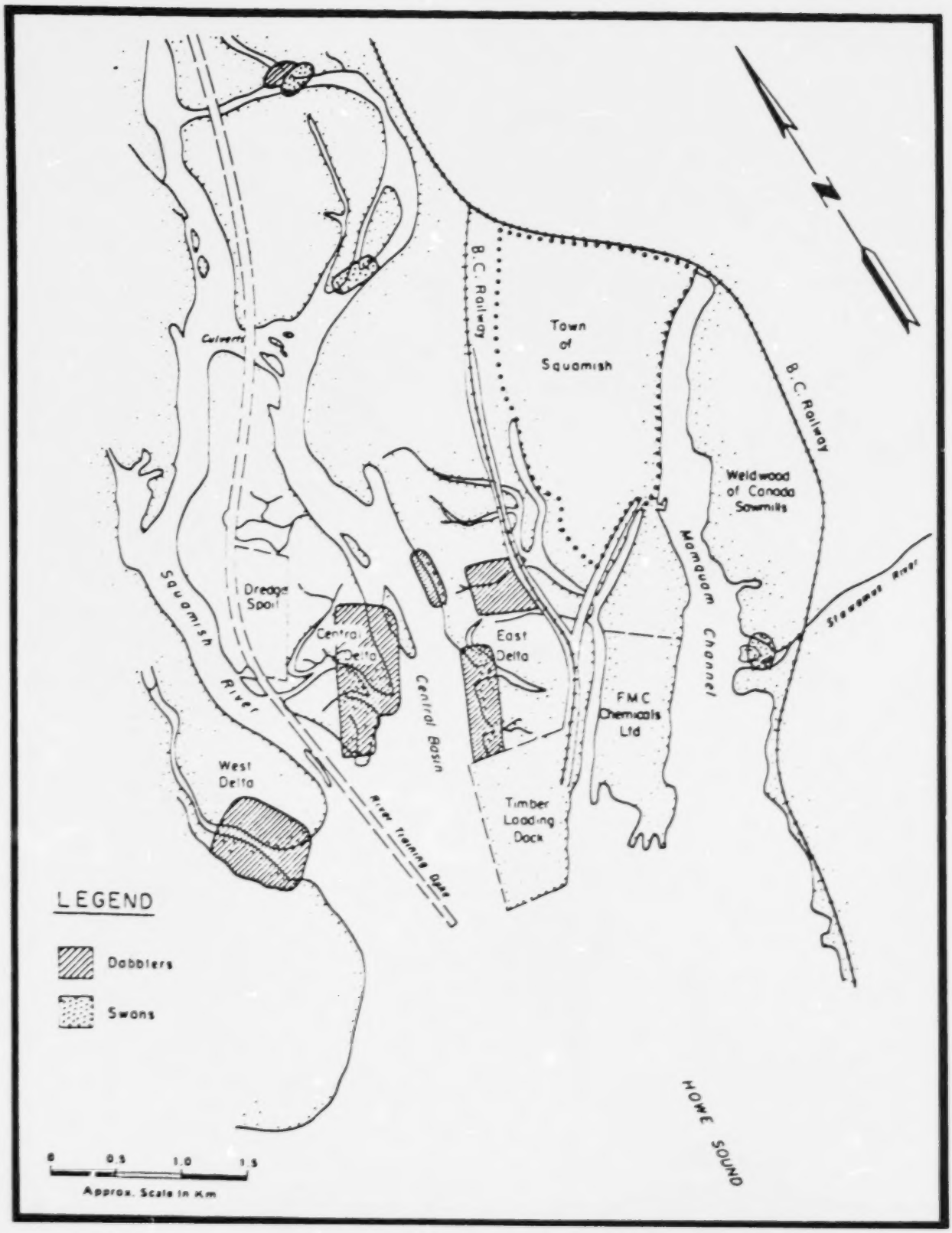


Figure 18. Approximate Locations of Dabbling Duck and Swan Concentrations at the Squamish River Estuary, October 1972 to May 1973

(Appendix A.3). Shifts in concentrations of dabblers from one part of the estuary to another during the study (Figure 19) probably were due to species preferences and seasonal availability of food.

Mallards: Mallards were the most abundant overwintering dabbler species. Their numbers began building in late October (later than for other dabbler species) and reached a peak of 135 in mid-November (Appendix B.6). Numbers then decreased as the last of the migrants apparently departed and about 50-60 birds remained as an overwintering population. In late January, the first spring migrants began to arrive and maximum numbers were seen mid-March to mid-April. Up to 372 mallards were seen per day during April, but by mid-May their numbers were less than 30.

Pintail: Pintail, the only other overwintering dabbler, were less numerous than mallards. Because most pintails normally migrate through the Fraser estuary in late summer (Kaiser, pers. comm.), it is likely that most of the fall migrant pintails also had passed through the Squamish estuary by early October. By late October, only a small wintering population remained (Appendix B.7). However, this population was not constant and fluctuated apparently in response to the weather. During December and January when daily mean temperatures dropped below freezing, larger numbers of pintails used the estuary only to leave again with the return of warmer weather (Appendices B.7 and B.8). Trethewey (1974) reported similar trends for dabblers at the Nanaimo River estuary during the winter of 1972-73.

As with mallards, spring migrant pintails began arriving at the Squamish estuary in late January. Peak numbers of pintails (up to 138 birds seen per day) occurred in early April and migration apparently was over by mid-May (Appendix B.7).

Teal and Wigeon: Green-winged teal and American wigeon apparently used the Squamish estuary only during spring and fall migrations (Appendices B.9 and B.10).

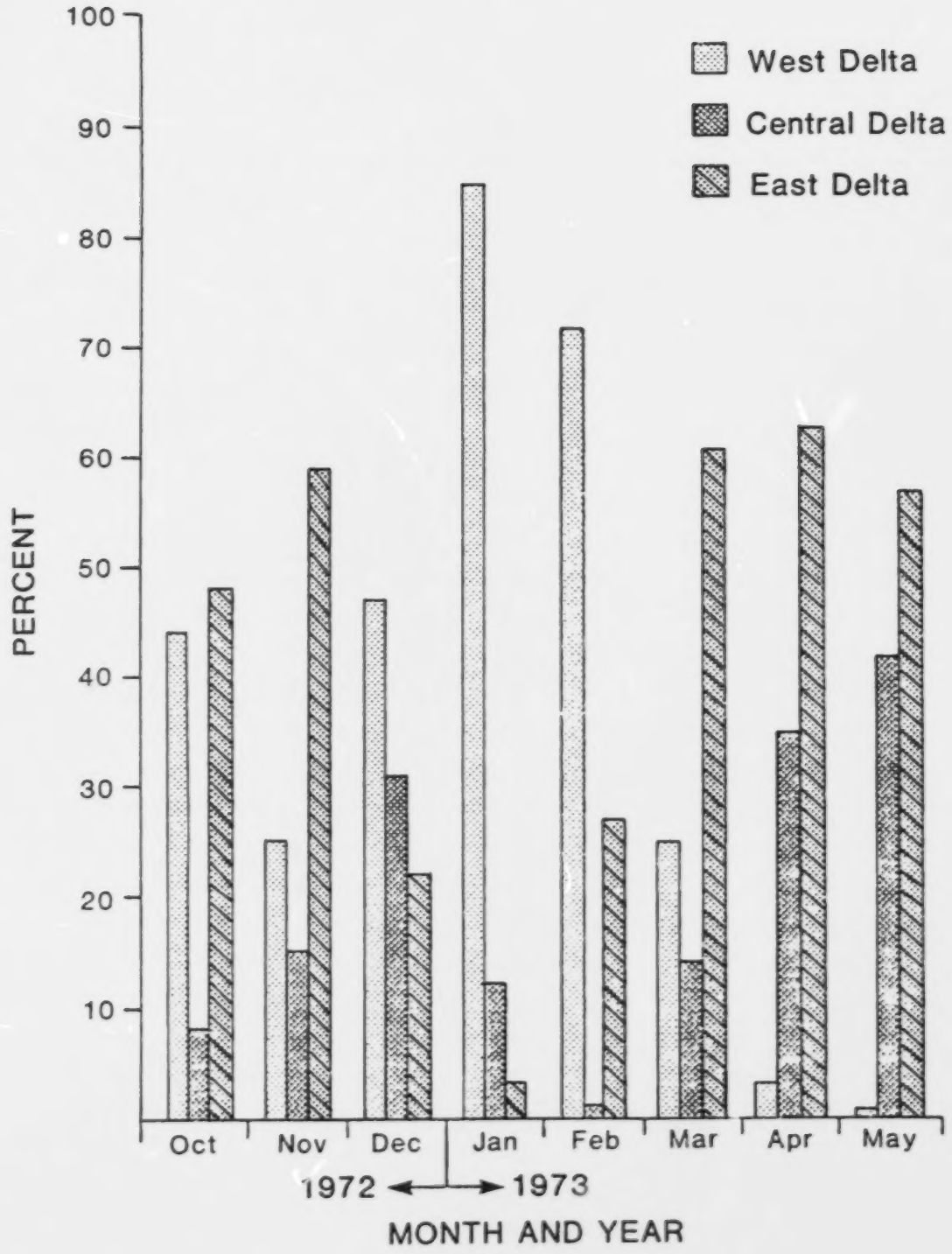


Figure 19. Percentages of all Dabbling Ducks Seen Each Month in Each of the Three Deltas at the Squamish River Estuary, October 1972 to May 1973

By early November, most teal had left the Squamish estuary and only a few birds remained until mid-December (Apppendix B.9). Except for scattered sightings during January, no teal were seen from late December until early March. The peak of the spring migration occurred in mid-April.

The first cinnamon teal were seen in early May when a maximum of six birds was seen, but is is probable that those birds were just the first of that species returning from their southern wintering areas. Because cinnamon teal and blue-winged teal (which were not seen although suitable habitat exists in the estuary) usually are among the first dabblers to migrate south in fall and among the last to migrate north in spring, it is probable that the C.W.S. study started too late and ended too early to record peak numbers of those species.

American wigeon used the estuary in a pattern similar to green-winged teal, but for shorter periods (Appendix B.10). From a maximum of 93 birds seen on the first count October 9, 1972, numbers of wigeon decreased steadily until by mid-November all had apparently left the estuary, not returning in significant numbers until mid-April. The most wigeon (89) recorded on one day were seen during the spring migration in early May. Because field observations ended in mid-May it was not possible to determine whether the large decrease in numbers on the last count was due to normal fluctuations in the migration pattern or whether the spring migration was over.

Other Dabblers: Northern shovelers were seen occasionally during October 1972, April and May 1973, and wood ducks were seen infrequently only during April and May 1973 (Appendix A.1).

iii. Geese

Canada geese, seen only once during the study (December 7, 1972) used the south end of the West delta against the mountain. Because Canada geese use the Bridge and Lillooet rivers for nesting

and Carpenter Lake for nesting and staging (University of B.C., 1970), the birds seen at Squamish may have originated in one of these general areas and used the estuary only as a resting place during migration.

iv. Swans

Trumpeter swans, the largest species of waterfowl in the world, also winter at the Squamish estuary. During the 1972-73 study, swans arrived late in November and departed by early March. In 1980, most swans did not leave until the third week of March (C.W.S. unpublished data). During 1972-73 up to eight swans were seen, but in 1980, that number had increased more than fourfold with up to 35 seen at one time.

The increase in the numbers of swans wintering at Squamish apparently did not suddenly occur during the 1979-80 winter, but has been ongoing since the mid-1970's (Reynolds, pers. comm. 1980). The increase at Squamish is consistent with similar increases in trumpeters at other estuaries on the southern coast and apparently is due more to the birds changing wintering areas than to a sudden increase in the size of the population (McKelvey, pers. comm.).

Preferred habitats for swans at the Squamish estuary were the northern portions of the Central basin during both the 1972-73 and 1980 surveys (Figure 18) although once during 1972-73, two swans were seen at the mouth of the Stawamus River on Mamquam Channel. Humphries (pers. comm.) reported that during the winter of 1978-79, trumpeter swans fed on the marshes of the Central delta at night.

British Columbia's estuaries are especially important as wintering habitat for trumpeter swans. Approximately one-half of the known world population of this species (which once was considered endangered and presently is classed as rare in the world) winters on the B.C. coast, mainly in, or adjacent to, estuarine areas (McKelvey, pers. comm.).

(b) Grebes

The grebe component of the bird population at the Squamish estuary ranked second at 28 percent of all birds seen and a mean number seen per day of 290 (Figure 20, Table XII, Appendices A.1 and A.2). Western grebes (78 percent) and horned grebes (16 percent) comprised 94 percent of all grebes seen (Appendix A.1). A maximum number of 863 grebes was seen in December. Red-necked grebes and pied-billed grebes were also seen occasionally.

Western Grebes: Large flocks of western grebes used the outer estuary throughout the winter. One-day counts ranged up to 772 birds, but numbers fluctuated widely during 1972-73 (Appendices A.1 and B.11). Low counts were believed the result of poor visibility, although the grebes may have moved out of the study area.

In fall, most western grebes were seen in the southeastern part of the outer estuary. In late January, the flock moved northward toward the river mouth and was seen most often in open water immediately south of the Squamish Terminals facility. By May, the flock began splitting into pairs for mating.

A flock of several hundred overwintering western grebes was seen regularly at Britannia Beach about thirteen kilometers south of Squamish, but those birds appeared to be a distinctly separate flock from that at the estuary. No indication of exchange or mixing within the two groups was observed.

Horned Grebes: Horned grebes were seen in scattered groups mainly in the lower Squamish River and in the Central basin. Numbers of horned grebes also fluctuated, although not as widely as western grebes, and a fairly constant number of about 50 birds was regularly seen (Appendices A.1 and B.12).

Martin et al. (1951) reported that both western grebes and horned grebes have similar diets of small fish, molluscs, aquatic insects, and other small crustaceans. The literature summarized by Hoos and Vold (1975) indicated an abundance of such organisms at the Squamish estuary.

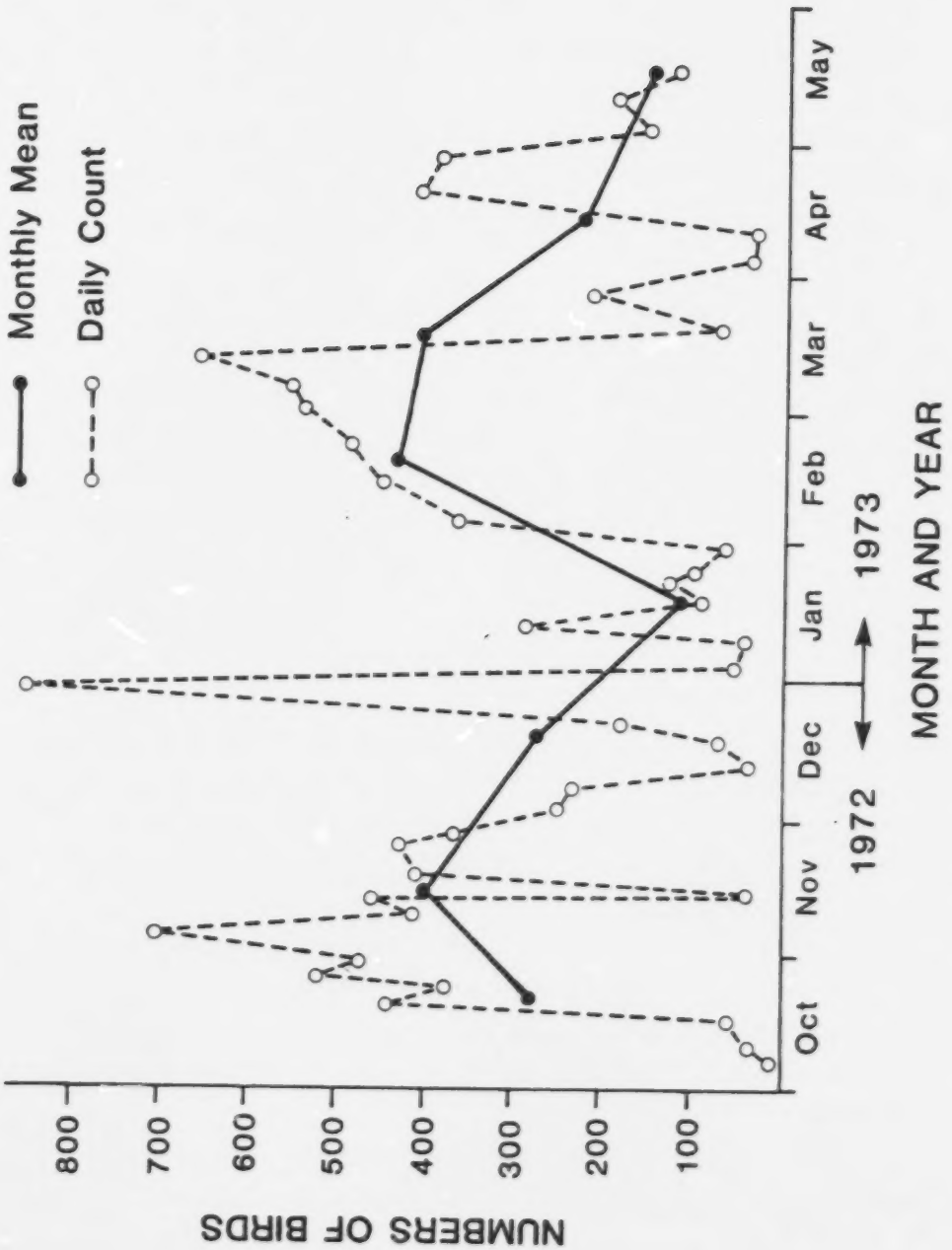


Figure 20. Numbers of Grebes Seen at the Squamish River Estuary, October 1972 to May 1973

(c) Gulls

Eight species of gulls were identified by Hoos and Vold (1975) as potential inhabitants of the estuary, although during the 1972-73 surveys only three species (glaucous-winged, mew and Bonaparte's) were identified (Appendix A.1).

Gulls were the third largest bird group seen at the estuary (Table XII) with large numbers (flocks of 800-1,100 birds) most common in December and January (Figure 21 and Appendix A.2). During winter, groups of gulls congregated at the mouth of the Squamish River, on the training dyke (especially on windy days) and on log booms in Mamquam Channel. A small flock of mew gulls occasionally was seen huddled on the ground on the East delta during strong winds.

Gulls were seen flying south out of the estuary in early evening and north up Mamquam Channel at dawn, but roosting sites or inland daytime destinations were undetermined. The town dump at the north end of the estuary did not receive much use by gulls and it is likely that many of the birds continued on upriver, out of the study area, to feed on salmon carcasses (in fall and winter). Passage Island, Pam Rock, and Christie Islet farther south in Howe Sound, are known to be nesting locations for gulls (Benson, 1971; Dept. of Environment 1973) and possibly those areas also serve as roosting sites.

(d) Other Waterbirds

Other groups of waterbirds seen during 1972-73 included loons, cormorants, alcids and coots which comprised 4 percent of all waterbirds recorded (Table XII).

i. Loons

Loons, which used many of the same areas as grebes, comprised less than one percent of the waterbirds seen during the C.W.S. surveys (Table XII). Almost 50 percent of the loons seen could not be identified to species, but of those speciated, common loons were

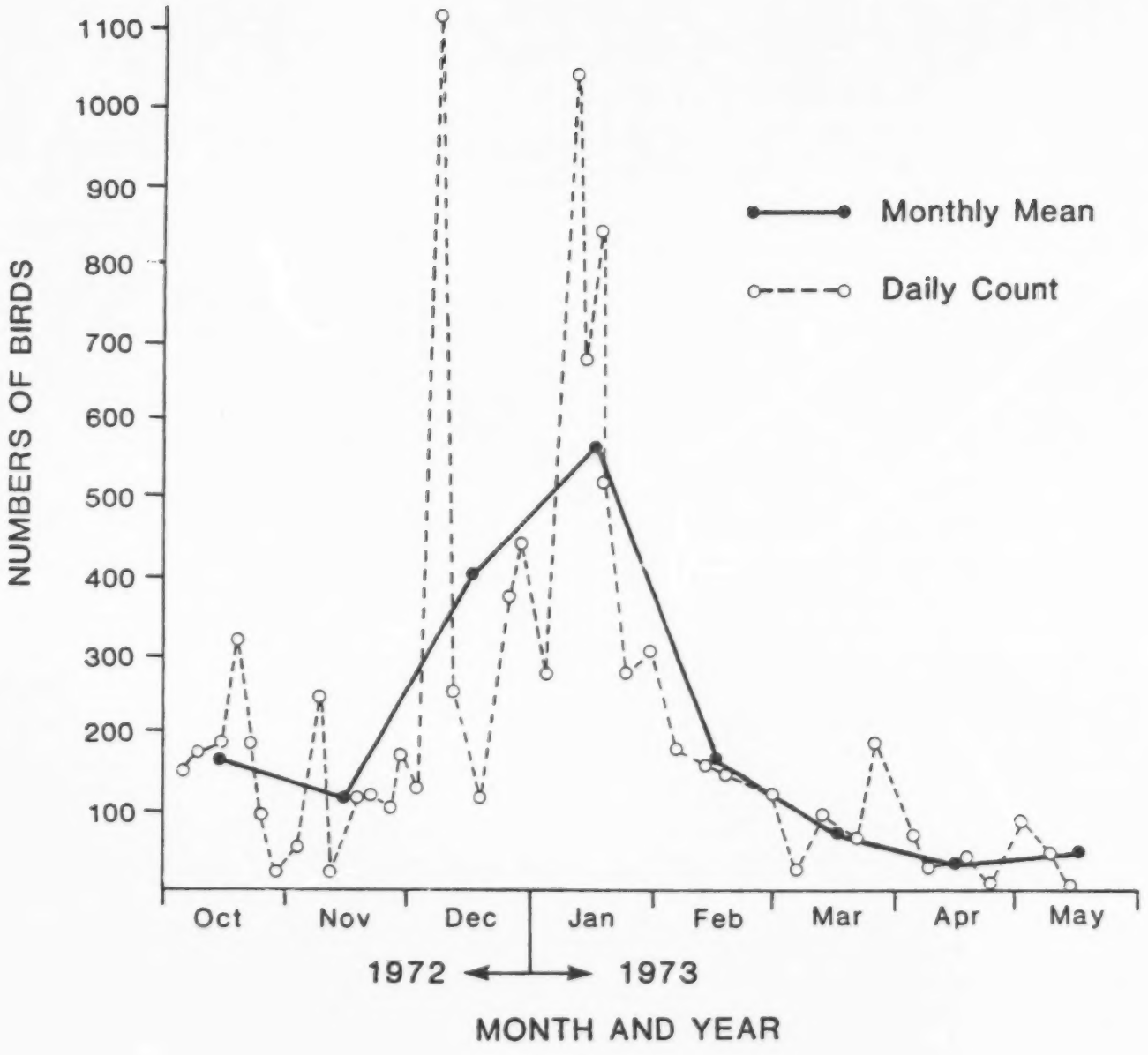


Figure 21. Numbers of Gulls Seen at the Squamish River Estuary, October 1972 to May 1973

most numerous during November and December while red-throated loons were most numerous January through March. Like the grebes, loons also feed entirely on animal matter. Fish (mostly species unsuitable for human food) are their main food items and are supplemented with crustaceans and molluscs (Martin et al., 1951).

ii. Cormorants

Cormorants comprised nearly three percent of all waterbirds seen during 1972-73 (Table XII). Only about one-third of the cormorants seen were identified to species and among those, only two species - pelagic and double-crested were recorded. Cormorants were first seen in November and most had left by mid-May. While at the estuary, cormorants loafed on the log booms in Mamquam Channel and fed in the same general areas as grebes and loons. Like loons, the food of cormorants consists mainly of coarse fish which is supplemented with invertebrates (Martin et al., 1951). The nearest known nesting colonies of double-crested and pelagic cormorants are located at Pam Rock, Passage Island, and Christie Islet (Benson, 1961; Dept. of Environment, 1973).

iii. Alcids

Only two species of alcids, marbled murrellets and common murres, were seen during the 1972-73 surveys, and, like the loons, comprised less than one percent of all waterbirds seen (Table XII). Marbled murrellets, which comprised almost 97 percent of the alcids, were seen only in the outer estuary and apparently rarely mixed with other birds.

iv. Coots

Only one coot was seen in October 1972, so it is probable that that bird was an accidental occurrence or that most coots had left the area before the surveys began and either do not use the estuary in the spring, or had not returned to the area before the study ended.

2.6.2.2 Herons

Great blue herons and one green heron were recorded at the Squamish estuary during the 1972-73 surveys. Although great blue herons were seen at the estuary during every month of the study, they were seen least often during December and January (Appendix A.1). Great blue herons were seen at least once in every sub-unit of the study area except the outer estuary, but 81 percent of the heron sightings occurred at the East delta, Central delta and intervening Central basin (Appendix A.3).

Great blue herons feed mainly on fish, amphibians, small rodents, and somewhat on crustaceans and molluscs which they obtain in fields, marshes, channels and shallow intertidal areas (Taylor, 1974; Kelsall, pers. comm.).

No heronries were identified in the vicinity of the Squamish estuary. The nearest known heronries are located just south of Port Mellon on the west side of Howe Sound, and on the southeast side of Anvil Island, 40 km and 20 km respectively from Squamish (Kelsall, pers. comm.; Mark, 1976).

2.6.2.3. Shorebirds

Shorebirds, such as sandpipers and plovers comprised about one percent of all birds seen at the Squamish estuary during the 1972-73 surveys (Table XII). However, the low numbers recorded may have been due to the restricted period of the study.

The small areas of mud flat in the East delta attracted a few shorebirds in the fall and spring, but only killdeer were seen regularly throughout the study (Appendix A.1). Long-billed dowitchers and western sandpipers were seen most often during October and November, while the least sandpipers were seen in May.

The food of most shorebirds consists mainly of small invertebrates (Bent, 1927 and 1929) and although food habits studies are

unavailable for shorebirds in southwestern B.C., the literature summarized by Hoos and Vold (1975) indicated an abundance of potential food organisms for shorebirds at the Squamish estuary.

2.6.2.4 Raptors

Birds of prey consist of hawks, eagles, falcons and owls. Of 18 raptor species listed by Hoos and Vold (1975) for the Squamish area, the 1972-73 C.W.S. surveys identified five species at the estuary (Appendix A.1).

One of the most unique aspects of the avian fauna of the Squamish area as a whole, and the estuary in particular, are the large numbers of bald eagles which gather along the Squamish River during fall and winter to feed on salmon carcasses. During the 1972-73 surveys, up to 53 eagles were seen per day at the estuary in late January and early February. Naturalist observations on file at the Provincial Museum in Victoria indicate sightings of much larger numbers of eagles from various locations upriver (Hoos and Vold, 1975). Jyrkkanen (pers. comm.) estimated that 1,000-1,500 bald eagles inhabit the entire Squamish system. Apparently, numbers of eagles seen in any given year fluctuate proportionately with the size of that year's salmon run, however, these concentrations are believed to be among the highest in North America.

Approximately 92 percent of all raptor sightings at the Squamish estuary during 1972-73 were of bald eagles (Appendix A.1). The remainder were divided among red-tailed hawks, marsh hawks, kestrels, golden eagles and unspeciated raptors.

Generally, raptors require abundant prey species, large open areas for easy hunting; and vegetation for perching, nesting and cover. At Squamish, such conditions are provided by the edges of intertidal areas, estuarine meadows, and fields.

2.6.2.5 Songbirds

Songbirds or passerines (perching birds) such as robins, crows, warblers and sparrows, comprised the fourth largest group of birds seen during the 1972-73 surveys, accounting for approximately 11 percent of all birds seen (Table XII). Of 74 species of songbirds listed by Hoos and Vold (1975) for the Squamish area, 16 were identified at the estuary during the 1972-73 surveys.

Starlings, crows and ravens comprised nearly 92 percent of all passerines seen. Red-winged blackbirds and unidentified passerines comprised nearly three percent and four percent of the sightings respectively, while the remaining one percent were scattered among 12 species (Appendix A.1).

The 1972-73 surveys probably underestimated the numbers of species and individual songbirds which use the Squamish estuary. That is probably due to several causes, for example:

1) the timing of the study was such that many migrants and potential summer resident species would have been missed,

2) many of the smaller species of songbirds are secretive, tending to stay in or near areas of heavier cover such as that found in the more northerly portions of the estuary where they must be actively searched for,

3) because the 1972-73 study was designed to concentrate mainly on waterbirds, other species were recorded only when seen during waterbird surveys.

2.6.2.6 Upland Game Birds

Upland game birds of the Squamish area include ruffed grouse and blue grouse. Of these, appparently only ruffed grouse inhabit areas adjacent the estuary. According to Reynolds (pers. comm.) and Harris (1972) the alder bottomlands near the estuary are productive of ruffed grouse. Generally, ruffed grouse prefer the edges of wooded areas, nesting in the forest, but using the edges for feeding.

2.6.2.7 Other Birds

Other birds not discussed previously include kingfishers and woodpeckers (common flickers) which comprised only about one-tenth of one percent of all birds seen at the Squamish estuary (Table XII).

2.6.3 Avian Habitat Requirements

In the previous section, references were made to various habitat characteristics which may have attracted certain species of species groups to specific parts of the estuary. To further substantiate those bird/habitat relationships at the Squamish estuary, a summary of known bird-use of similar habitat elsewhere is presented below. Similarly, in the absence of adequate bird-use data, areas of potentially important habitat may be identified by investigating characteristics of available habitat and assessing its importance according to known bird-use of similar habitat elsewhere.

2.6.3.1 Foreshore Vegetation

Areas of foreshore vegetated by marsh, algae, or eelgrass (Zostera spp.) are usually important migratory waterbird habitat. For example, dabbling ducks, geese and swans may eat parts of marsh plants or eelgrass, or certain of the green algae such as sea lettuce (Ulva spp.).

Vegetation not eaten directly by birds may contribute to their food supply indirectly through the detrital food chain. In that situation, when vegetation dies it decomposes and provides food for small intertidal invertebrates which then are eaten by birds, or are eaten by larger organisms, which are in turn eaten by birds. Generally, the latter route is the means by which most diving birds such as diving ducks, grebes, and loons obtain much of their food. Some dabbling ducks also forage for invertebrates on the intertidal areas at low tide. In addition, marine algae and eelgrass provide food and cover for many prey species of diving birds.

Intertidal and shallow subtidal vegetation is used by herring as a substrate on which to spawn. Such areas of herring spawning habitat are important to certain species of migratory birds because many birds eat either the herring spawn or the fish themselves. During a major herring spawn, gulls and diving birds may be attracted from a considerable distance (Trethewey,1979). Thus, any re-establishment of herring spawning at the Squamish estuary would be of benefit to migratory birds.

2.6.3.2 Spawning Salmon

A number of species of birds depend for a part of the year on salmon eggs and carcasses along the lower portions of streams having salmon runs. Gulls, eagles, and diving ducks are typically associated with such situations, but some dabbling ducks and even trumpeter swans are also known to feed on salmon carcasses (Butler, 1973).

2.6.3.3 Water Depth

Although diving ducks may eat some marine vegetation, they rely mainly on marine invertebrates as food. Some species may dive to several hundred feet for food, but most species which winter in southwestern B.C. apparently prefer to feed in water up to 6-8 fathoms (11-15 metres) in depth (Mitchell, 1952). Thus, all intertidal areas between the high tide line and subtidal areas out to the 8-fathom elevation (or deeper) are potentially important feeding areas for diving ducks.

In addition, dabbling ducks may follow the tide in and out across the intertidal areas feeding on marine plants and invertebrates. Thus, the generalization might be made that the greater the area of the intertidal zone and the adjacent subtidal zone out to approximately the 8-fathom elevation, the potentially better the habitat for waterfowl (unless certain extreme conditions make it unfavourable habitat for food species).

The marsh vegetation of the three deltas of the Squamish estuary was partially mapped by Lim and Levings (1972) who identified ten major vegetation communities in each of those areas (Section 2.3.3). A search of the literature relating to wildlife food habits indicated that some part of most of the main plants of each community were eaten by migratory birds, particularly waterfowl, shorebirds, and songbirds.

2.6.4 Information Gaps

Many aspects of wildlife biology and habitat relationships at the Squamish estuary are poorly understood. Although sufficient data exists to document the dependency of wildlife species on the estuary as a whole, in many cases individual data is insufficient to identify specific habitat types of special importance to individual species. Some areas which require further study are:

1. The inventory and biology of all wildlife species using the estuary.
2. The relationships between habitat units and the wildlife species which use them.
3. The rates of turnover among migratory species using the estuary.
4. The interrelationships between the wildlife species using the estuary.

3.0 AREAS FORMALLY DESIGNATED OR PROPOSED FOR FISH AND/OR WILDLIFE PROTECTION

The following areas within the Squamish estuary study area have been designated or proposed for protection:

(1) A municipal reserve located above Mamquam Channel adjacent to the high school. The municipality leases this 10.5 ha reserve to the School Board on a five year term. The lease is due for renewal in 1982. 4.45 ha of this land belongs to B.C. Rail and 6.07 ha belongs to the Water Board.

(2) The Department of Fisheries and Oceans (1976) has identified areas which do not contribute significantly to estuarine productivity, based on their 1972 report, Effects of Existing and Proposed Industrial Development on the Aquatic Ecosystem of the Squamish Estuary. The Department recommended that all areas of the estuary be protected except:

- that portion of Mamquam Channel northeasterly of the public docking site,
- all areas enclosed by flood control dykes,
- where dykes are not present, all areas above extreme high tide mark and separated from this demarcation by an adequate site specific green-belt area,
- shoreline areas on both east and west sides of Howe Sound south of the Squamish River delta.

(3) The District of Squamish and Squamish Chamber of Commerce presented a brief to the Minister of Fisheries on March 1, 1979, to outline a proposed plan which could lead to environmentally compatible industrial development of the estuary. The brief recommended that areas of the Squamish estuary west of the B.C. Railway line serving the Squamish Terminals Dock be considered for conservation.

(4) The Squamish Estuary Nature Centre Committee (ad hoc.) prepared a brief proposing a Squamish Estuary Nature Centre dated July 17, 1979, to be located on the Central and East deltas.

4.0 LAND USE EFFECTS ON AQUATIC AND TERRESTRIAL HABITATS

The purpose of this section is to identify past land use practices, developments and activities which have altered the productive nature and capacity of both aquatic and terrestrial habitats. This includes both industrial and urban aspects, but leaves water quality modifications due to effluents (both industrial and sanitary) to the Water Quality Work Group report. General land use impacts are discussed first in a historical perspective. Discussions of specific modifications, both detrimental and beneficial, are presented by habitat and by causative factor.

4.1 General Land Use Impacts

Squamish was first settled as a farming community in the late 1870's. The importance of agriculture as a mainstay in the local economy was short-lived, as subsequently forestry, mineral and transportation developments have provided the basis of sustained economic growth since the beginning of the century.

Outside the study area, but in the immediate vicinity, is the Woodfibre pulp mill which started operating in 1912. The mill has slowly expanded and is now operated by Western Forest Industries. In June 1966, the mill and associated residential development were annexed by the District of Squamish, and in the early 1970's the residential area at Woodfibre was closed down.

Sawmilling was not very significant in Squamish until relatively recently. In 1962, Canadian Collieries Resources Limited opened a large sawmill and associated logging operation. This sawmill and logging division have since been taken over by Weldwood of Canada Limited. In 1964, MacMillan Bloedel Limited decided to use Squamish as the base for a new logging division. Both MacMillan Bloedel's and Weldwood's operations are located in Mamquam Channel.

Historically, mining in the area has been to the south at the Britannia Beach copper property. Development work was initiated in 1902, and by 1930 the mine employed an estimated 1,000 men. Operations were curtailed during the depression and later in 1958 when low copper prices rendered the mine uneconomic. Labour disputes and poor markets caused intermittent closures during the 1960's. Finally, the mine ceased operation in 1974.

The railway has been an important contributor to the development of Squamish. In 1909, construction of the Howe Sound and Northern logging railway was completed. This line was later taken over by the Pacific Great Eastern Railway (PGE) which completed the line between Squamish and Lillooet in 1915. Shortly thereafter, the provincial government took over the PGE and construction of the Lillooet-Quesnel section was completed in 1921. Later extensions to Prince George, the Peace River, and the Squamish-North Vancouver link added to the workload of the yard and repair shops in Squamish.

In 1976, at the time of the last census, 8,368 persons were reported as living in Squamish; about twice the number reported in 1966. Population statistics are not available for years prior to 1966 for the area presently comprising the District of Squamish. However, it is estimated that the 1956 population of the district was in the order of 2,500. Between 1966 and 1976, population growth in Squamish averaged seven percent per annum. Although industrial expansion in the Squamish area has been an impetus to population growth, some of the observed increase during the past decade is attributed to the development of the surrounding area's recreational potential and the influx of persons who live in Squamish and commute to Vancouver.

The District of Squamish covers 10,852 ha from the head of Howe Sound up the Squamish valley. The community is arranged such that the commercial and retail area is at the southern end of the municipality and residential areas are located at intervals up the valley. Zoning bylaws are in effect to control development and land use. A substantial supply of unoccupied land appears to exist in all zoning classifications.

Since 1971, construction of new housing in Squamish averaged 280 units per year; with single family units comprising roughly 65 percent of the new additions and multiple family dwellings, 35 percent. The existing housing stock is estimated to be about 3,400 units; twice that reported in 1971. While the observed increase in the housing stock can be partially attributed to growth in the economy of the local area, an increasing number of persons employed in Vancouver are taking up residence in the community.

Industrial firms on the delta not covered above in the historical perspective are FMC of Canada Limited and Squamish Chemicals (Hooker Chemicals Division of Canadian Occidental Petroleum Limited). Both are located on reclaimed land on, and north, of the old rail terminal in the East delta area. Other developments, such as dyking and the forest products terminal, are discussed below.

4.2 Modification of Aquatic Habitats

The four main areas of modifications encountered are: dyke and training wall, fill and reclamation, dredging, and log storage.

The dyke and training wall, completed in 1972, have had effects other than the direct alienation of habitat by removing it from the aquatic realm. Bank characteristics have been modified, although alder have been allowed to colonize the bulk of the structure. Further, with the dredging (-1.5 m and 107 m width, to 1,646 m north from the mouth) of the river channel, the bed load has increased and is predominantly sandy, while the almost isolated central area of the estuary has become siltier and more saline.

Figures 22 to 26 show progressive landfilling from 1930 to 1972. Most filling has occurred shoreward from the old rail terminal (presently FMC and Squamish Chemicals), at Squamish Terminals Ltd. (accounting for 17 ha west of Cattermole Creek), and an additional 14 ha filled during the construction of the training dyke.

Dredging is also carried out annually along most of the length of Mamquam Channel. Nineteen thousand to 55,000 m^3 are removed and dumped in at least 35 m of water off the delta front.

Lastly, log storage has been carried out in nearly every area of the estuary (Figures 22 to 26). Recently, most is in Mamquam Channel with additional activity in the Central Basin. Log storage and related activities are associated with habitat degradation from logs grounding and scour from propwash, debris smothering the bottom, and shading.

4.3 Modification of Terrestrial Habitats

Many developments common to the estuary have resulted in direct or indirect modifications of terrestrial habitat, or to the use of habitat by wildlife species. General developments, and their possible effects are as follows:

- Industry and general urbanization; through land development, facility construction, and day-to-day activities causing alienation of natural habitat as well as disturbance by noise or activity. Another often overlooked aspect is that of competition and harrassment of wildlife by domestic animals.

- Transportation; again noise disturbance, but having the added impact of lighting, road kills and bird strikes (aircraft).

- Utilities; location of transmission lines in flight paths thereby causing bird mortalities.

- Recreation; much the same impacts as transportation, but hunting pressure could be added.

- Agriculture; biocides, plus unspecific agriculture which alienates habitat.

It should be noted that not all effects of development are detrimental, as beneficial effects are enjoyed by some opportunistic species through increased roosting and nesting habitat, and additional food sources for scavengers. Also, agricultural activities may directly or indirectly provide food and habitat for some species. Lastly, beneficial effects are also the planned result of reserve and conservation areas.

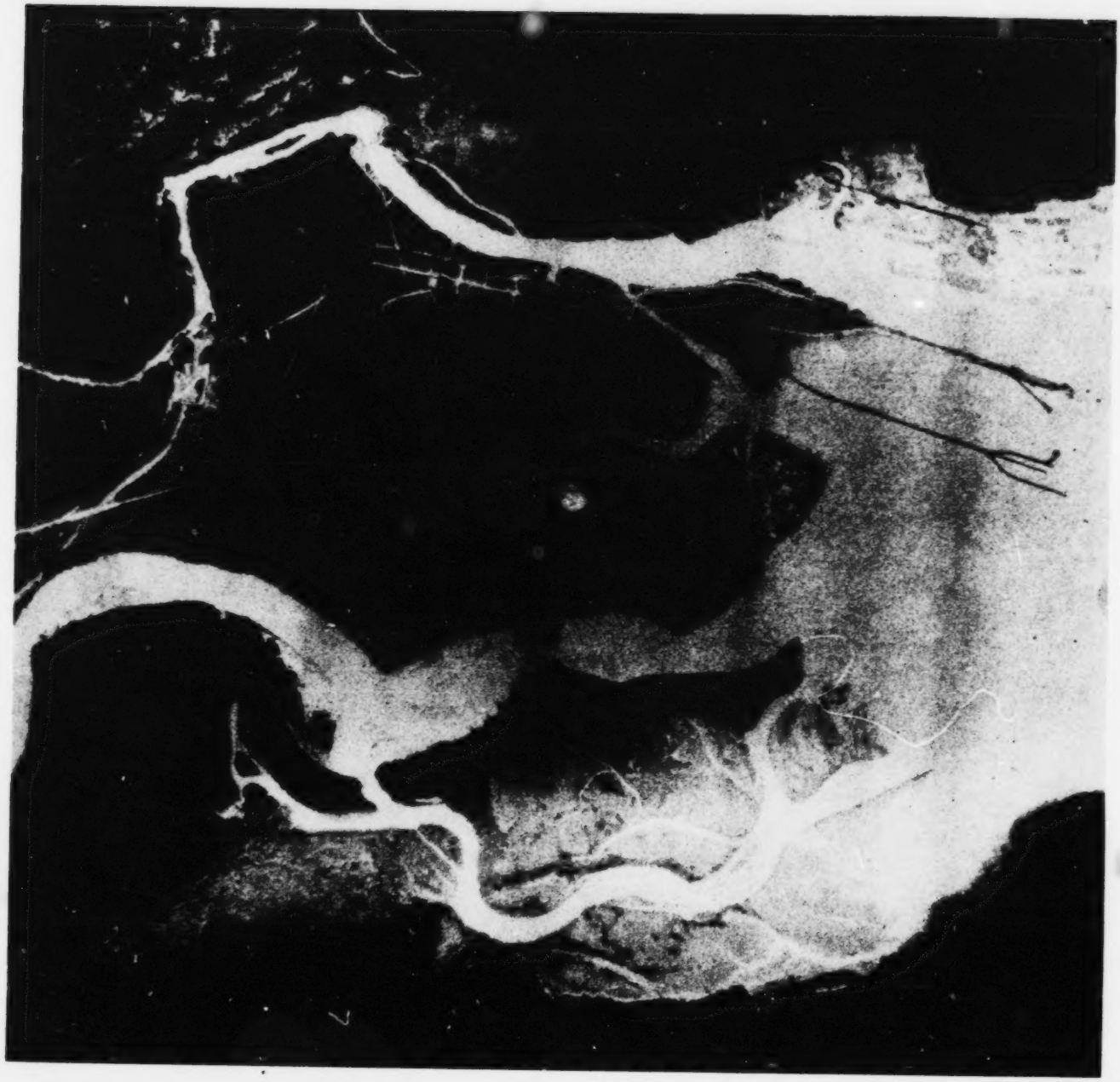


Figure 22. Squamish Estuary: August 1930

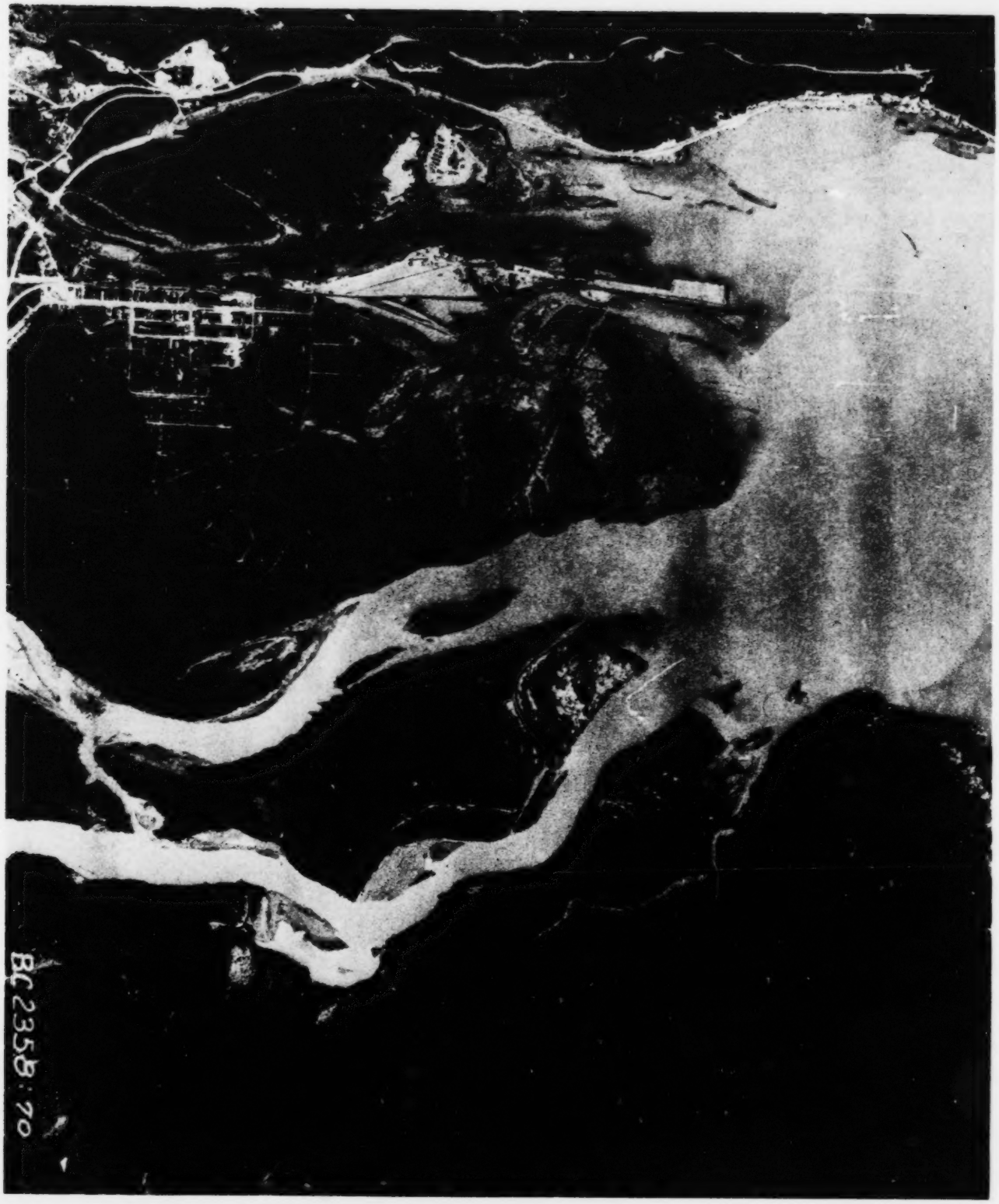


Figure 23. Squamish Estuary: September 1957

Figure 24. Squamish Estuary: May 1963

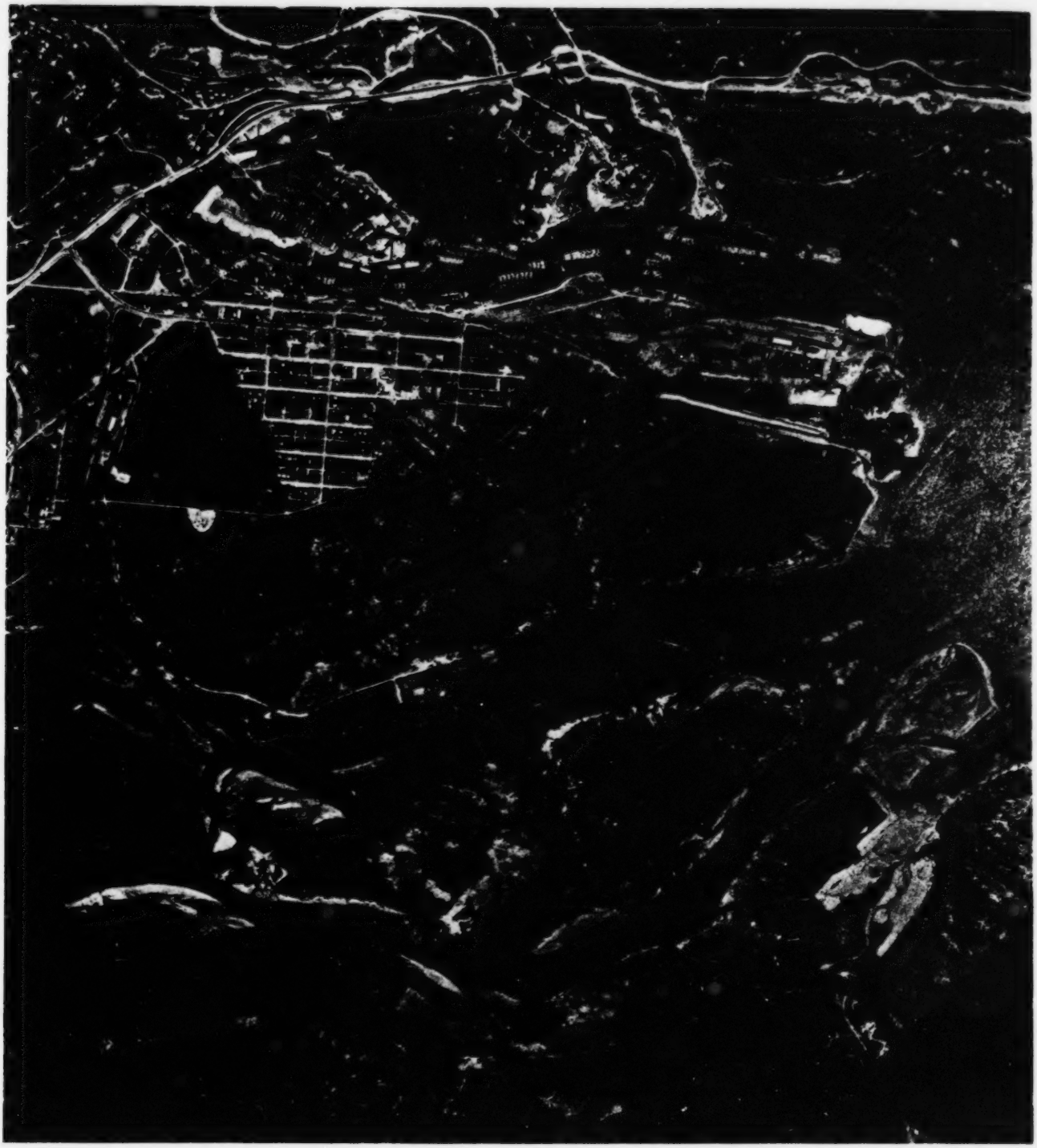


Figure 25. Squamish Estuary: May 1968

Figure 26. Squamish Estuary: June 1972

5.0 TERRESTRIAL, INTERTIDAL, AND AQUATIC HABITAT ZONES

A biophysical habitat classification system was developed for the Squamish estuary and broad habitat zones and habitat classes were mapped. The work was undertaken using information from a variety of existing studies and literature sources, and from the interpretation of 1:8000 scale colour aerial photographs (flown March, 1973) and 1:10,000 scale black and white aerial photographs (flown July, 1979). Several days of ground truthing wereundertaken in June of 1980.

The habitat classification is biophysically based, using vegetation cover types and substrate as the main criteria for delineating map units. The study area is divided into four major habitat zones and these zones are each subdivided into a number of natural units termed habitat classes.

5.1 Habitat Classification Mapping

Two 1:5000 scale habitat classification maps were prepared by the Ministry of Environment, Terrestrial Studies Branch, for the Squamish River Estuary Management Study. One set of mylar overlays for use in conjunction with 1:5000 scale Squamish estuary orthophotos were prepared, and these are available as original material for reference purposes from the Assessment and Planning Branch Map Library, Ministry of Environment, Victoria.

For this report, a 1:10,000 scale habitat classification map was prepared as an overprint on a reduced Squamish estuary orthophoto. A folded copy of this map is enclosed (Appendix C).

The habitat classification categories and symbols used in mapping are summarized as follows:

Habitat Zones		Habitat Classes	
Zone Symbol		Class Number	
O	Open Water	1.	Deep water estuarine
		2.	Shallow water estuarine
		3.	Shallow water riverine
		4.	Brackish slough
I	Intertidal	1.	Open mud/sand flats
		2.	Tidal drainage channels
		3.	Low marsh
		4.	Intermediate marsh
		5.	Upper marsh
B	Backshore/Lowland	1.	Estuarine meadow
		2.	Estuarine shrub
		3.	Riverine gravel bars
		4.	Pioneer shrub
		5.	Deciduous forest
		6.	Mixed deciduous-coniferous forest
		7.	Disturbed - undeveloped
		8.	Developed - industrial/residential
U	Upland	1.	Pioneer shrub
		2.	Deciduous forest
		3.	Mixed deciduous-coniferous forest
		4.	Coniferous forest
		5.	Scrub/rock
		6.	Developed - industrial/residential

The Open Water map units were difficult to delineate accurately and are constantly being modified by hydrologic processes. To indicate this problem, a dashed line is used between these habitat classes. The separation between Deep water estuarine and Shallow water estuarine was made using the 10 metre depth line from the Canadian Hydrographic Service's Howe Sound 1978 chart.

5.2 Habitat Classification Table

A detailed description of the various habitat classes, including the approximate area of each class, and an indication of the main fish or wildlife use, is shown in the Squamish Estuary Habitat Classification Table (Table XIV).

TABLE XIV: SQUAMISH ESTUARY HABITAT CLASSIFICATION TABLE

OPEN WATER ZONE

MAP CODE	HABITAT CLASS	HABITAT DESCRIPTION	AREA, ha (% of total)	FISH AND/OR WILDLIFE USE
01	Deep water estuarine	This habitat unit includes that portion of the Open Water Zone where water depth is greater than 10 meters. Salinity within this unit varies considerably, with the lower water layers, generally more saline and with the waters in the vicinity of the Squamish River mouth significantly brackish. Phytoplankton are the main primary producers in this habitat type and zooplankton the primary consumers.	43.9 (4.7)	- Harbour seals, killer whales - Most important for pelagic feeding diving birds (loons, grebes, alcids, cormorants) - Some use from diving ducks and gulls - Fish (salmon, trout, char, herring, rockfish, dogfish, flounders, soles, sculpins, needlefish) - Dungeness crabs - Phytoplankton and zooplankton production
02	Shallow water estuarine	This habitat unit includes those marine water areas that occur between the low tide mark and a depth of 10 meters. Salinity generally increases with depth and from west to east with the Squamish River mouth brackish. Benthic algae are the main primary producers, while amphipods (an important prey of fish) are important consumers.	123.7 (13.3)	- Harbour seals, occasional use by mink and otters - Considerable use by diving ducks and limited dabbling duck use - Fish (salmon, trout, char, herring, sculpins, sand lance, eulachons, perch, starry flounders) - Dungeness crabs - Phytoplankton, zooplankton, benthic algae, benthic invertebrates
03	Shallow water riverine	This habitat unit includes all regularly flowing fresh water streams. The largest units are the Squamish and Mamquam rivers. The substrate in the lower 2 km of the Squamish River is mainly sands and silts whereas upstream and in the lower Mamquam River, sands and gravels predominate.	120.0 (12.9)	- Harbour seals (in larger, deeper channels) - Mink, otters, raccoons - Occasional ospreys, eagles - Diving ducks (mergansers, goldeneye), limited dabbling duck use, diving birds (loons, cormorants, grebes), and gulls - Trout (cutthrout) and char (Dolly Varden) resident and migratory populations - Salmon migration, spawning, rearing - Sculpins and crayfish

SQUAMISH ESTUARY HABITAT CLASSIFICATION TABLE (cont'd)

OPEN WATER ZONE CON'T

MAP CODE	HABITAT CLASS	HABITAT DESCRIPTION	AREA, ha (% of total)	FISH AND/OR WILDLIFE USE
04	Brackish slough	This habitat unit includes portions of tidal channels in which drainage has been restricted by dykes or road beds. Although these units are mainly receiving areas for fresh water, some salt water mixing occurs at higher tides through culverts in the barriers. Aquatic vegetation in these areas is dominated by widgeon grass (*Ruppia maritima*). Water fringe vegetation consists of cattail (*Typha latifolia*), sedges (*Carex* spp), sowthistle (*Sonchus arvense*), baltic rush (*Juncus balticus*), Pacific silverweed (*Potentilla pacifica*) and various grass species (*Poa*, *Hordeum*, *Dactylis*, *Agrostis* spp.). These areas are usually backed by deciduous shrubs such as black twinberry (*Lonicera involucrata*), salmonberry (*Rubus spectabilis*) and elderberry (*Sambucus racemosa*), as well as young alder (*Alnus rubra*).	6.0 (0.7)	- Mink, raccoons - Diving ducks, dabbling ducks, herons, shorebirds; use dependent on water depth - Songbirds (long-billed marsh wrens, red-winged blackbirds, yellow-headed blackbirds) use edges for nesting - Fish (salmon, trout, char, sculpins) - Benthic invertebrates (including crayfish) aquatic insects - Zooplankton production
		Zone Total	294.5 (31.6)	

SQUAMISH ESTUARY HABITAT CLASSIFICATION TABLE (cont'd)

INTERTIDAL ZONE

MAP CODE	HABITAT CLASS	HABITAT DESCRIPTION	AREA, ha (% of total)	FISH AND/OR WILDLIFE USE
I1	Mud/sand flats	This habitat unit supports benthic algae but no vascular plants. The substrate ranges from clayey silt to sand with sand being the predominant substrate in the west delta portion of the estuary. This classification is also used for several riverine sandbars in the Squamish River that are inundated and exposed daily as a result of tidal action.	80.9 (8.7)	- Mink, raccoons (at low tide stages); otters harbour seals (at higher tide stages) - Herons, eagles - Dabbling ducks, geese, swans, gulls (at low tide stages); diving ducks (grebes, loons, cormorants) at higher tide stages - Fish (including salmonids) feeding at higher tide stages - Dungeness crabs - Benthic algae and invertebrates - Major detritus producer and source of nutrients for the estuary and adjacent marine areas
I2	Tidal drainage channels	This habitat unit consists of the channels which drain intertidal portions of the estuary. These channels generally possess silty organic mud beds with banks of alternating layers of silts, sands and sedge root mats. These channels are fringed with dense strands of Lyngbye's sedge (Carex lyngbyei) and minor amounts of spike rush (Eleocharis palustris) and low clubrush (Scirpus cernuus). Some of the larger channels, specifically the Central basin, support patches of widgeon grass along their upper reaches.	19.0 (2.0)	- Harbour seals at higher tide stages, some mink, raccoons, otters - Bird use similar to I1; additionally swans in northern portion of Central delta - Fish (salmonids, surf smelt, sculpins, flounders, sticklebacks); rearing and feeding - Benthic algae and invertebrates (sedge rhizomes at low marsh edge important amphipod habitat) - Major detritus producer and source of nutrients for the estuary and adjacent marine areas
I3	Low marsh	These areas are characterized by the presence of Lyngbye's sedge in robust homogeneous stands, and represents one of the most important estuary areas from a biological production point of view. It is in this unit that this species reaches its most vigorous form, growing as high as 1.25 meters in places. This habitat type is located in both the lower portion of the intertidal zone as well as lining the tidal drainage channels throughout the mid and upper portion of the zone. In the lower parts of this unit, frequent pan areas are found and Lyngbye's sedge associated with small amounts of spike rush, low clubrush, seaside arrowgrass (Triglochin maritimum) and in one area at the mouth of Mamquam Channel, with dense mats of rockweed (Fucus sp.). In the upper areas Lyngbye's sedge is associated primarily with water parsnip (Sium suave) and water hemlock (Cicuta douglasii). Substrates are silty organic muds throughout.	76.8 (8.2)	- Mink, raccoons - Dabbling ducks, swans, geese (important feeding habitat) - Diving ducks, diving birds, herons (at higher tide stages) - Songbirds, raptors (minimal), and shorebirds (when vegetation flattened) at lower tide stages - Fish (salmonid rearing, sticklebacks, sculpins) - Sedge rhizomes at low edge of marsh important amphipod habitat - A major detritus producer and source of nutrients for the estuary and adjacent marine areas.

SQUAMISH ESTUARY HABITAT CLASSIFICATION TABLE (cont'd)

INTERTIDAL ZONE CON'T

MAP CODE	HABITAT CLASS	HABITAT DESCRIPTION	AREA, ha (% of total)	FISH AND/OR WILDLIFE USE
I4	Intermediate marsh	This habitat generally occurs in the middle portions of the intertidal zone. The dominant vegetative cover consists of Lyngbye's sedge, Pacific silverweed (Potentilla pacifica) seaside arrowgrass and Baltic rush with varying amounts of lilaeopsis (Lilaeopsis occidentalis), spikerush, Alaska plantain (Plantago maritima), Red fescue (Festuca rubra), tufted hairgrass (Deschampsia cespitosa), water hemlock, Springbank clover (Trifolium wormskioldii), marsh pea (Lathyrus palustris) and Eaton's aster (Aster eatonii) are present in the higher parts of this habitat unit. Soils are silty gleysols with some organic content. The units are dissected by drainage channels and contain frequent pan areas.	29.5 (3.2)	- Some use by blacktail deer - Mink, raccoons - Birds (similar to I3 although less diving duck and diving bird use) - Fish (salmonids, sculpins, sticklebacks) dependent on tide levels - Reptiles and amphibians - Insects and benthic invertebrates (production primarily on vegetation stalks) - A major detritus producer and source of nutrients for the estuary and adjacent marine areas
I5	Upper marsh	This habitat occurs in the upper intertidal zone and is characterized by a drier regime, being inundated only during the higher storm tides. The vegetation is dominated by grasses, predominantly reed canarygrass (Phalaris arundinaceae), meadow barley (Hordeum bracyantheum) and creeping bentgrass (Agrostis alba). Red fescue, tufted hairgrass and Poa spp. are present. These areas are further characterized by herbs such as Lynghye's sedge, marsh pea, rice root (Frittelaria camschatcnesis), water hemlock and Eaton's aster. Dominance is shifted to cattail, Lyngbye's sedge, Pacific silverweed and Baltic rush in water filled depressional areas within this unit. Soils are silty gleysols.	18.8 (2.0)	- Black bears, deer, and coyotes - Mink, raccoons, and other small mammals - Dabbling ducks, swans, geese, when flooded - Raptors, songbirds (more than in I3 and I4) - Reptiles and amphibians - A major detritus producer and source of nutrients for the estuary and adjacent marine areas
		Zone Total	225.0 (24.1)	

SQUAMISH ESTUARY HABITAT CLASSIFICATION TABLE (cont'd)

BACKSHORE/LOWLAND ZONE

MAP CODE	HABITAT CLASS	HABITAT DESCRIPTION	AREA, ha (% of total)	FISH AND/OR WILDLIFE USE
B1	Estuarine meadow	This unit consists of drained backshore areas which have been utilized in the past for hay cropping and pasture. They are dominated by forage grasses (Poa, Dactylis, Agrostis, Festuca, Holcus, Hordeum and Phalaris spp.), as well as Pacific silverweed, sowthistle, vetch (Vicia gigantea), and creeping buttercup (Ranunculus repens). Wetter areas within this unit support sedges, Baltic rush, dock (Rumex spp.), water hemlock, cattail (Typha latifolia), Pacific silverweed and seaside arrowgrass. A shrub thicket (salmonberry, rose, elderberry) fringe is persistent throughout this area.	30.2 (3.2)	- Occasional use by black bears, deer, coyotes - Mice and voles - Dabbling ducks (when flooded), shorebirds (when vegetation flattened), herons, raptors, songbirds - reptiles and amphibians
B2	Estuarine shrub	This habitat unit occurs at higher elevations within the estuary on old fluvial bars and ridges and generally forms a fringe between the upper marsh/estuarine meadow vegetation and lowland forest types. The units are characterized physically by an accumulation of driftwood and by regosolic soils. Shrubs such as willow (Salix spp.), elderberry, salmonberry (Rubus spectabilis), Nootka rose (Rosa nutkana), wild crabapple (Pyrus fusca), black twinberry and Sitka spruce (Picea sitchensis) are common. Herbs associated with this unit are dominated by grasses (Poa, Bromus, Agropyron, Hordeum, Festuca spp.) and Lyngbye's sedge. Other common species include Pacific silverweed, seaside arrowgrass, shooting star (Dodecathon pulchellum), deerberry (Maianthemum dilatatum), water parsnip, water hemlock and wild carrot (Daucus carota).	15.9 (1.7)	- Occasional use by black bears, deer, coyotes - Mice and voles - Songbirds, raptors, occasional ruffed grouse - Reptiles

SQUAMISH ESTUARY HABITAT CLASSIFICATION TABLE (cont'd)

BACKSHORE/LOWLAND ZONE CON'T

MAP CODE	HABITAT CLASS	HABITAT DESCRIPTION	AREA, ha (% of total)	FISH AND/OR WILDLIFE USE
B3	Riverine gravel bars	These units are exposed predominantly sandy to gravelly bars which are annually flooded. They are largely unvegetated and occur mainly in the lower Mamquam and Squamish River area.	12.0 (1.3)	- Eagles, gulls, black bears and some furbearers scavenge salmon carcasses
B4	Pioneer shrubs	This habitat unit occurs adjacent to the main rivers on sites subject to annual flooding and on other recently disturbed lowland sites. The predominant vegetation is willow (Salix spp.) and red alder but a variety of other deciduous shrubs are also present.	32.6 (3.5)	- Deer - Occasional use by black bears, coyotes, and other furbearers - Ruffed grouse and songbirds
B5	Deciduous forest	This habitat unit is moderately well represented in the study area occurring commonly in the vicinity of the Squamish River. The predominant tree species are alder and cottonwood (Populus trichocarpa), and a well developed shrub layer is present.	77.4 (8.3)	- Black bears, deer, coyotes, other furbearers - Arboreal small mammals (squirrels, bats) - Birds (similar to B4 although more cavity nesters) - Raptors and possibly herons may use larger trees as roosts or for nesting
B6	Mixed deciduous-coniferous forest	This habitat unit occurs over a large portion of the undeveloped valley floor. The predominant deciduous tree species are alder, cottonwood and maple (Acer macrophyllum). The dominant coniferous species are Sitka spruce, western red cedar (Thuja plicata) and western hemlock (Tsuga heterophylla).	116.6 (12.5)	- Similar to B5 except eagle nesting likely and songbird diversity greater
B7	Disturbed-undeveloped	This designation includes a variety of unvegetated land units on the valley floor that have been disturbed but have not been significantly developed. Such areas are dredging spoil sites, landfill areas and unimproved roads.	36.1 (3.9)	- Wildlife use extremely low except near edge habitats - Garbage dump may attract scavenger species
B8	Developed-industrial/residential	This designation includes a number of developed areas on the valley floor. Industrial operations, residential areas, roads and rail lines are included in this category.	79.3 (8.5)	- Small mammals - Songbirds use residential areas for cover, feeding and nesting
		Zone Total	400.1 (42.9)	

SQUAMISH ESTUARY HABITAT CLASSIFICATION TABLE (cont'd)

UPLAND ZONE

MAP CODE	HABITAT CLASS	HABITAT DESCRIPTION	AREA, ha (% of total)	FISH AND/OR WILDLIFE USE
U1	Pioneer shrub	This habitat unit includes the majority of recently logged or burned sites above the valley floor. The vegetation is comprised primarily of a variety of deciduous shrubs and regenerating coniferous trees.	0.9 (0.1)	- Similar to B4 but abundance and diversity lower
U2	Deciduous forest	This habitat unit is uncommon above the flood-plain but where it occurs the main species is red alder.	3.5 (0.4)	- Similar to B5 but abundance and diversity lower
U3	Mixed deciduous-coniferous forest	This habitat class is well represented on the valley slopes. Common tree species are Douglas fir (Pseudotsuga mensiesii) red alder and broad-leaf maple.	0.9 (0.1)	- Similar to B6 but abundance and diversity lower
U4	Coniferous forest	This habitat type occurs on the east and west valley slopes. Douglas fir and western hemlock are the dominant tree species.	8.2 (0.9)	- Similar to B6 but abundance and diversity lower
U5	Scrub/ rock	This habitat type occurs on areas with shallow soils and exposed bedrock. A variety of shrubs and stunted coniferous trees are characteristic vegetation. A significant portion of the valley slopes both east and west of the estuary is included within this habitat class.	*	- Black bears, deer, cougars, bobcats - Potential raptor nesting - Songbirds
U6	Developed-industrial/ residential	Includes a number of developed areas above the valley floor on the east side of the valley. Residential sites, mill sites, gravel pits, roads and rail lines are included in this category.	*	- Similar to B8
		Zone Total	13.5 (1.5)	

* Outside Management Plan Boundary

6.0 SYNTHESIS OF HABITAT CLASS PRIORITIES

These priorities must be qualified in that the classification system on which they are based (Section 5.0) is somewhat artificial. This is because the estuary operates as a unit; the interrelationships of habitat classes are important but not fully understood; and the borders of classes as indicated are not absolute boundaries, but clines. Furthermore, the classification must be considered provisional as it was based almost entirely on literature sources and photo-interpretation with only a minimum of ground verification. Nonetheless, these priorities, or ranks of relative importance, should be of assistance to the decision-making process of management.

6.1 Definitions of Priorities

Definitions of levels of priorities (degree of importance) were established before assigning relative importances to any given classification. These are:

CRITICAL: Areas absolutely necessary for continuing present levels of production of estuarine dependent species. Considered essential as part of the study terms of reference for maintaining present levels of biological productivity.

IMPORTANT: Areas of high usage by estuarine dependent species. Not critical for reasons of habitat abundance or productivity.

MODERATE: Areas not heavily used by estuarine species, nor tied directly or closely to estuarine production, but possibly significant for some species.

LIMITED: Areas severely disturbed and those upland areas of no direct or close connection to estuarine production.

A total of 933.1 ha was examined within the boundaries of the study area. Additional nearby areas, mainly uplands (pioneer shrub, deciduous forest, mixed deciduous-coniferous, scrub/rock and developed), were classified as having limited importance. Of the 933.1 ha; 355.6 ha (38 percent) were classified as critical, 163.9 ha (18 percent) as important, 284.7 ha (31 percent) as moderate, and 128.9 ha (14 percent) as limited.

6.2 Assignment of Priorities

Assignment of priorities was based on existing habitat conditions. Primary determinants were the degree of importance to estuarine productivity in general, and estuarine dependent fish and wildlife in particular.

Information was derived from literature sources, fish and wildlife management agencies, specialists in related fields, and, where data were lacking, inferred by the working group from known habitat utilization data from other estuary studies.

Priorization of habitat classes was generated by the Habitat Work Group. Each habitat class' utility to the primary determinants was discussed and a priority nominated. Once all classes were initially priorized, their priority was re-examined and confirmed.

6.3 Habitat Class Priorities

Table XV summarizes habitat class priorities and Figure 27 maps these priorities. Specific use of habitat classes by fish and/or wildlife is detailed in Section 5.0 (Table XIV). It is the intent that Table XV be used as a guide for decision-making and not necessarily as a zoning format for conservation or development plans. A particular development may be compatible with a given habitat class should the development not significantly reduce the biological productivity of the habitat. Conversely, development proposals for conservation purposes may have the potential to adversely affect the biological productivity of a habitat class. Therefore, even this type of development may be judged as incompatible with a habitat class in a given situation.

6.4 Habitat Management Guidelines

Management guidelines have been developed for each habitat priority rating. These guidelines indicate, in a general way, how each of the habitat priorities should be managed. In addition, they indicate the acceptability of development for each area, as well as the manner by which proposed developments should be assessed. The guidelines are as follows:

CRITICAL: No use should be permitted that would adversely affect the biological productivity of the habitat. This does not mean that development is precluded, however, each proposed development would be subject to a stringent environmental impact assessment. The likelihood of development approval would probably be low in most instances. Recreational activities such as hunting, fishing, and bird-watching would be acceptable, whereas, activities which could damage habitat, such as off-road vehicle use, would be unacceptable.

IMPORTANT: Some activities and developments may be acceptable, however, an environmental impact assessment would be required to ensure that the activity or development does not appreciably affect the overall productivity of the estuary.

MODERATE: Activities and developments proposed for these areas should be referred to appropriate agencies for review. As a result of such a review, an environmental impact assessment may be warranted.

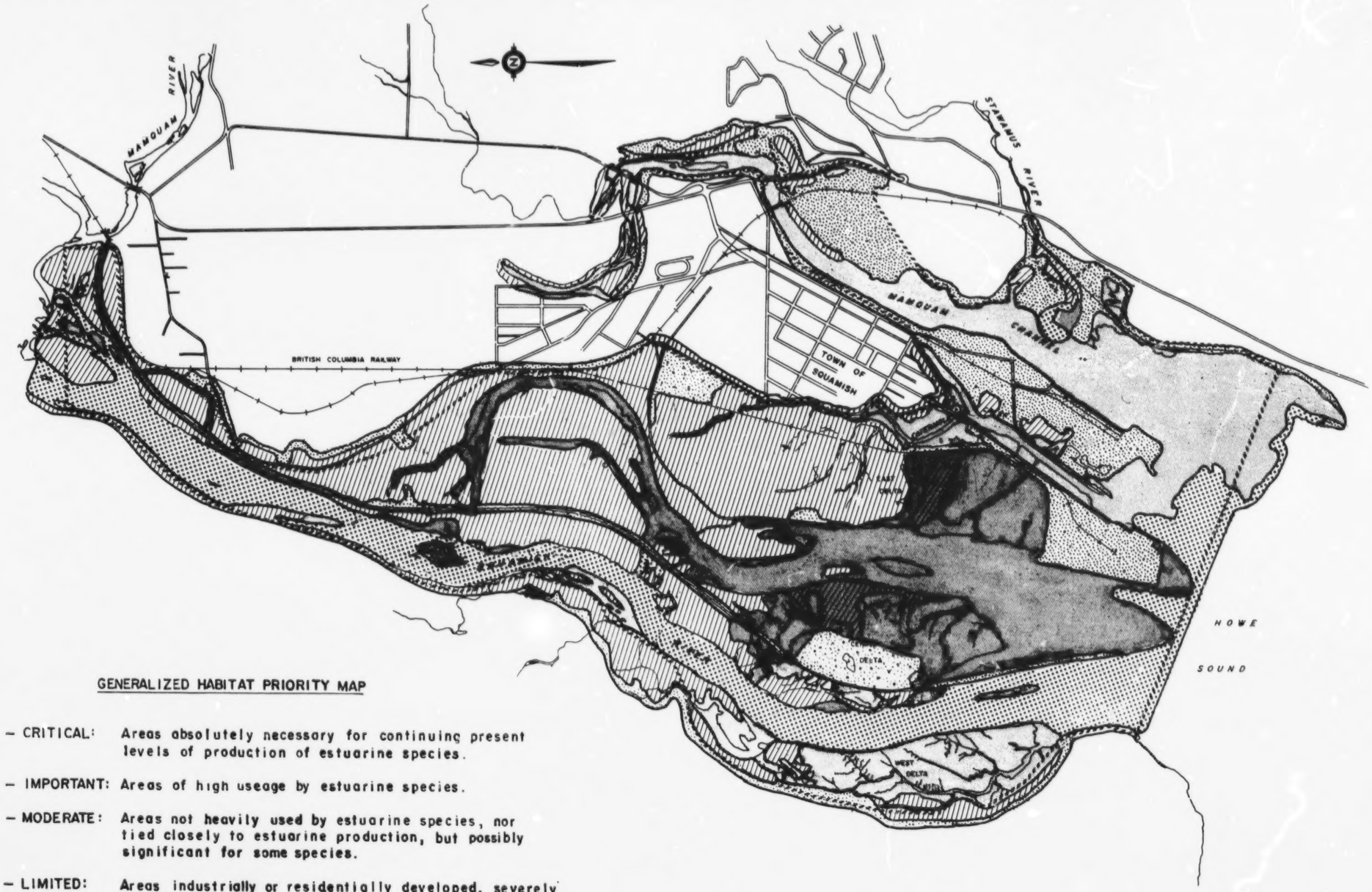
LIMITED: These are the preferred areas for development, however, proposed developments must abide by existing environmental regulations. Consideration should be given to potential impacts of development on adjacent habitat types.

TABLE XV: HABITAT CLASS PRIORITIES

PRIORITY	CLASS
CRITICAL	Shallow water estuarine
	Brackish slough
	Open mud/sand flats
	Tidal drainage channels
	Low marsh
	Intermediate marsh
	Upper marsh
IMPORTANT	Deep water estuarine
	Shallow water riverine
MODERATE	Estuarine . eadow
	Estuarine shrub
	Riverine gravel bars
	Pioneer shrub (1)
	Deciduous forest (1)
	Mixed deciduous-coniferous forest (1)
LIMITED	Disturbed-undeveloped (1)
	Developed-industrial/residential (1)
	Pioneer shrub (2)
	Deciduous forest (2)
	Mixed deciduous-coniferous forest (2)
	Coniferous forest (2)
	Scrub/rock (2)
	Developed-industrial/residential

(1) Backshore/Lowland Habitat Zone

(2) Upland Habitat Zone



GENERALIZED HABITAT PRIORITY MAP

- CRITICAL: Areas absolutely necessary for continuing present levels of production of estuarine species.
- IMPORTANT: Areas of high useage by estuarine species.
- MODERATE: Areas not heavily used by estuarine species, nor tied closely to estuarine production, but possibly significant for some species.
- LIMITED: Areas industrially or residentially developed, severely disturbed, or upland areas with no close connection to estuarine production.

Province of British Columbia — Ministry of Environment

SQUAMISH ESTUARY MANAGEMENT PLAN STUDY AREA

FIGURE No. 27

7.0 HABITAT RESTORATION AND ENHANCEMENT

7.1 Problems and Concerns

The overriding concern of the Habitat Work Group is the continued viability of the estuary through preservation of estuarine habitat and maintenance of water quality. Historically, development of the estuary has not considered the estuary's importance to fish and wildlife resources, nor the fact that the estuary largely functions as a unit which should not be subdivided into isolated compartments.

7.1.1 Direct Loss of Habitat

Considerable direct loss of habitat has occurred over the years. It is difficult to measure the effect of this loss on fish and wildlife populations and on the overall productivity of the estuary. Nonetheless, a substantial amount of certain habitat types known to be utilized by a variety of fish and wildlife species has been alienated. This situation makes the remaining habitats all the more valuable.

7.1.2 Degradation of Habitat

Certain activities may be degrading the quality of the remaining habitat within the estuary. For example, the water quality of many areas within the estuary has been degraded due to sewage discharges, industrial effluents, wood debris from log handling and sawdust loading facilities, leachates from woodwaste landfills, and occasional spills of fuel and wood preservatives.

Recent studies have shown that salinity levels in the Central and East deltas are higher than they were prior to construction of the training wall. In some cases, this has already led to changes in vegetation occurring in these areas which in turn may alter fish and wildlife habitat values. Also, the blocking of tidal channels has removed their availability to rearing salmonids and has affected the flow of nutrients into other portions of the estuary. It has also resulted in the growth of terrestrial vegetation in the upper parts of the Central delta which will eventually lead to a net loss of intertidal habitat.

7.2 Habitat Restoration and Enhancement Opportunities

There are a host of possible habitat restoration and enhancement opportunities within the Squamish River estuary. Specific recommendations regarding restoration and enhancement have been formulated by the Habitat Work Group. No feasibility or cost/benefit analysis has been done for any of the following recommendations. Therefore, priorization of the recommendations is not possible at this time. Feasibility and cost/benefit studies would be required before any restoration or enhancement work is undertaken. Figure 28 shows the locations of the sites pertaining to opportunities 1 through 7. The more generalized restoration/enhancement opportunities (8 through 11) that could occur in several parts of the estuary are not shown in the figure.

(1) A structure could be built to protect the remaining West delta from the eroding forces of the Squamish River. (The feasbility, location, cost, and maintenance of such a structure would have to be assessed by a hydrological engineer.)

Rationale: Construction of the training dyke and confinement of the Squamish River into one channel has resulted in the loss of 12.0 hectares of the West delta due to erosion.

(2) An assessment should be undertaken to determine if it would be beneficial to install water control structures and/or additional culverts through the training dyke to increase fresh water flow to the Central basin.

Rationale: The training dyke has altered water circulation patterns (primarily the freshwater influence of the river) to the Central basin. Possible benefits of increasing fresh water flow to the basin would be in maintenance of the "natural" condition of the area, improved flushing, reduced salinities, and an overall improvement in fish and wildlife utilization and capability.

(3) An assessment should be undertaken of the feasibility of restoring the area affected by the 1972 dredge spoil site (adjacent to the training dyke) to a biologically productive state.

Rationale: Creation of the dredge spoil site adjacent to the training dyke destroyed approximately 14.2 hectares of productive Carex sp. marsh.

(4) Consideration should be given to relocating the log handling and storage facilities in the Central basin to a more environmentally acceptable location.

Rationale: The log handling and storage facilities in the Central basin are generating a considerable amount of wood debris which adversely affects the productivity and integrity of the habitat as well as water quality.

(5) An assessment should be undertaken of the benefits of removing the accumulation of logs and other wood debris from the west side of the railway adjacent to the East delta.

Rationale: The accumulation of this debris may be adversely affecting the biological productivity of the area.

(6) The meadow formerly dyked from the upper intertidal (refer to Figure 28) should be restored to a more biologically productive state by either reconnecting the meadow to the Central basin, or by improving the dyke and managing the area as a brackish impoundment.

Rationale: The meadow is not currently being utilized to its full biological capability.

(7) The sedge marsh east of the B.C., Railway mainline should be reconnected to Howe Sound by installing water control structures under the railbed.

Rationale: Water circulation between the marsh and Mamquam Channel would be improved which would not only permit increased nutrient exchange, but would also allow fish to utilize the marsh.

(8) Nesting structures could be erected in several parts of the estuary for Canada geese, wood ducks, and possibly mallards.

Rationale: Beyond the obvious benefits to nesting birds, the major value of such a program would be in public involvement and support for the wildlife resources of the estuary.

(9) Tidal channels partially or totally isolated from the remainder of the estuary by man-induced or natural causes should be reconnected to Howe Sound.

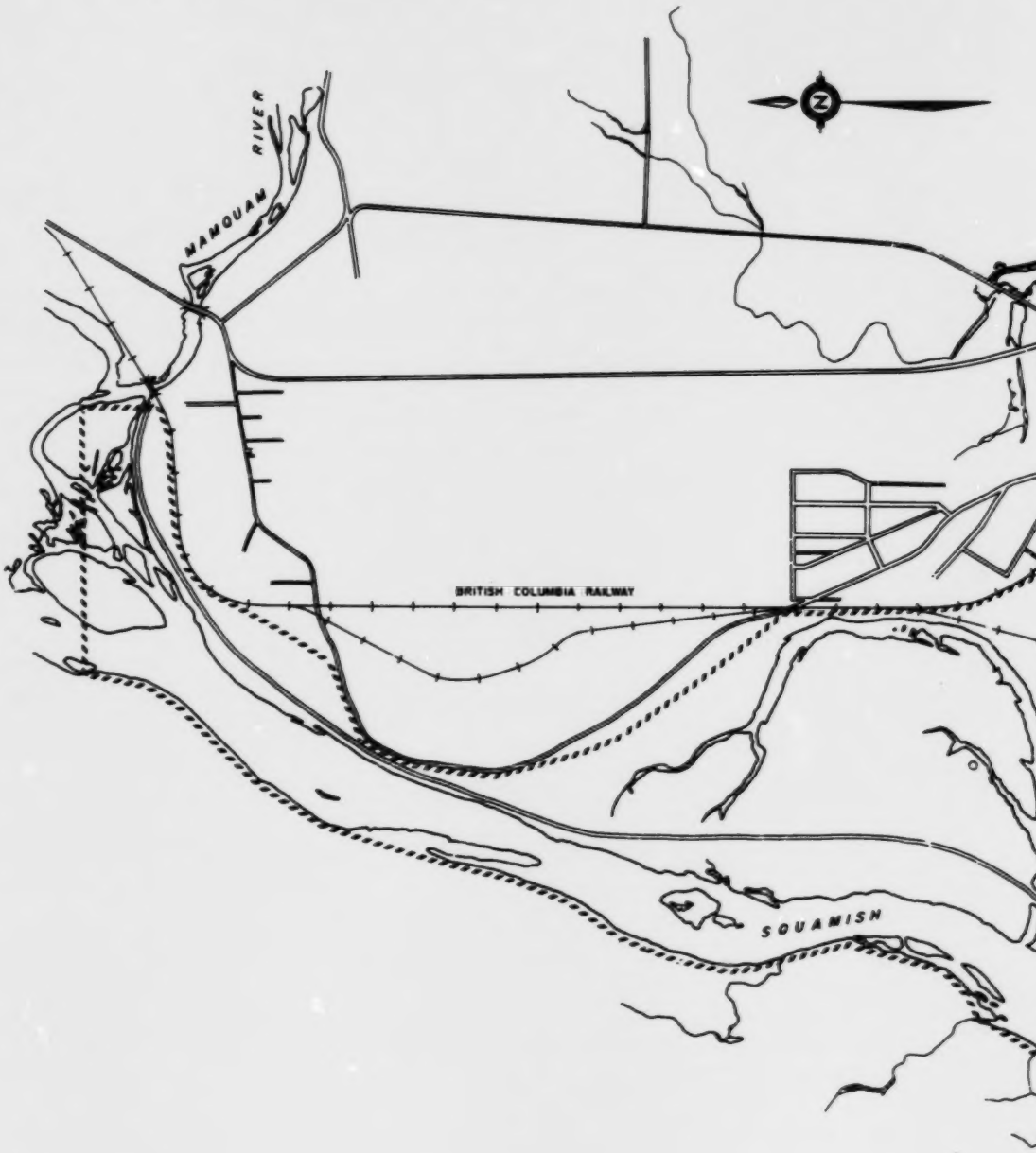
Rationale: The full potential of these channels for use by salmonids, other fish, and waterfowl is not being reached. In addition, nutrients and detritus which would normally be transported to the outer portions of the estuary via these channels are trapped.

(10) An assessment should be made of the feasibility of re-establishing eelgrass in the estuary.

Rationale: Eelgrass beds are extremely valuable to biological productivity. They provide a spawning substrate for herring, a food source for some species of waterfowl, cover for crabs and invertebrates, and a source of detritus for the estuary.

(11) More stringent conditions should be placed on the activities located along Mamquam Channel, particularly on the effluents discharged to the channel from these activities.

Rationale: The biological productivity of the channel would be enhanced by more stringent control of detrimental activities.



HABITAT RESTORATION / ENHANCEMENT SITES

SPECIFIC SITES FOR HABITAT REHABILITATION

AND ENHANCEMENT OPPORTUNITIES NUMBERED 1 TO 7

Province of British Columbia — Ministry of Environment

SQUAMISH ESTUARY MANAGEMENT PLAN STUDY AREA

FIGURE No. : 28

8.0 CONCLUSIONS AND RECOMMENDATIONS

The importance of the Squamish River estuary to a variety of resident and migratory fish and wildlife is, as yet, incompletely understood. The information that exists, however, indicates that the estuary is critical to at least certain stages of the life cycles of a number of economically and socially important species; and contributes significantly to the richness of adjacent waters of Howe Sound and even beyond in the Strait of Georgia.

Estuaries and marshes are amongst the most productive biological communities on earth. In discussions on land use of estuaries such as the Squamish, one question that invariably arises is, "How much wetland must be preserved to meet fish and wildlife management objectives?" Little quantitative information exists on the degree to which present productivity is utilized and, in the absence of such information, that question cannot be answered. Nor is it possible at present to quantify the losses of fish and wildlife that might be caused by any reduction of the existing system. We do know, however, that development of the Squamish area has resulted in a substantial reduction in the amount of wetland habitat within the estuary and floodplain system. It has also been demonstrated that, within limits, biological systems possess a remarkable ability to sustain productivity in the face of gradual attrition. Some species may disappear and overall numbers may drop, but the changes are so gradual as to be relatively imperceptible in the short term. When pushed beyond a certain point, however, changes become rapid, catastrophic and, for some species, irreversible.

The Squamish River and its estuary supports major populations of salmon and trout that contribute to commercial, native and recreational fisheries. The Squamish steelhead fishery is considered one of the finest in the Lower Mainland and one of the better fisheries in the entire province. Many other species of fish also utilize the estuary. Some can be found year-round whereas others are temporary residents.

The Squamish estuary also supports a variety, and abundance of wildlife, including waterbirds, shorebirds, raptors, harbour seals, furbearers and big game animals. The estuary is particularly important to

waterfowl both as migratory and wintering habitat. Trumpeter swans, the largest species of waterfowl and currently classified as rare, winter in the Squamish estuary.

The fish and wildlife that frequent the Squamish estuary rely to varying degrees on some or all of the major habitat zones within the estuary. Our ability to maintain and perhaps enhance those fish and wildlife resources is contingent upon our ability to conserve and manage what remains of the estuary. With this objective in mind, the following recommendations are offered:

1) The habitat management guidelines presented in Section 6.4 of this report be adopted as policies within the management plan.

2) The data gaps identified throughout the Habitat Work Group report should be filled as soon as possible, since it is this lack of information which makes it so difficult to assess the impact of proposed developments on the estuary as a whole, and the impact of habitat loss or degradation on fish and wildlife populations.

3) Thorough ground truthing of the Habitat Classification Map should be undertaken to verify the boundaries of habitat types and the accuracy of classifications.

4) A detailed assessment of the habitat restoration and enhancement opportunities described in Section 7.0 should be undertaken and implementation of those that prove feasible acted upon as soon as possible.

5) A monitoring program should be implemented to keep track of changes to the extent and condition of the habitat base as a result of both natural and anthropogenic causes.

SUMMARY

The Squamish River Estuary Management Study was initiated by the Federal and Provincial governments to develop, through the direction of four technical work groups, a management plan for the lower Squamish River and estuary. The Habitat Work Group's terms of reference provided for a basic delineation and description of habitat units and their utilization within the estuary, as well as an identification of factors affecting the habitat units, and opportunities for habitat restoration or enhancement.

Marine, Brackish, and Freshwater Areas

Sources of fresh and salt water are the fundamental determinants of the distribution of fresh, brackish, and marine water areas in the estuary. The Squamish River and its two main tributaries, the Cheakamus and the Mamquam, provide the main input of fresh water into the study area. The Strait of Georgia is the source of salt water. Despite variations in salinity distribution by a number of factors, it is possible to identify areas on the Squamish delta influenced more by fresh water than are others. Generally, areas near the river mouth and shallow areas are less saline than deeper sites. Because freshwater input is restricted to the west side of the delta by the training dyke, water of the West delta is less saline than that of the Central and East deltas and Mamquam Channel. The training dyke culverts allow a freshwater lens to develop in the Central basin during high flows, but this lens does not penetrate to the seaward edge of the basin. Under low flow conditions, salt water has been detected 1.5 km up the main river channel, 1.5 km up the Central basin, and 1 km up Mamquam Channel. A more detailed study of salinity distribution undertaken during low (March) and high (June) flow periods would be beneficial.

Substrates

It has been observed that sedges have acted to trap silts and clays carried by the river with the results that sediments in tidal marshes are dominated by silty-clays. Sediment deposition and distribution on the West delta shows coarser sediments than those of the Central delta. This is possibly a result of the West delta being subject to greater river flows and the protection of the Central delta by the training wall which blocks waves during strong southerly winds.

Differences in salinity regimes may also account for the variation in sediment coarseness. The delta front is covered by sandy-silts. The confinement of river flow has resulted in rapid accretion on the West delta front while the East and Central delta fronts are showing signs of erosion.

Plant Associations and Primary Productivity

Benthic algal species diversity and annual net productivity on the Squamish River delta have been noted to be greatest east of the training dyke because of the more stable, higher salinity habitat than that of the West delta. Production, distribution, and diversity of benthic algae are greatest in late winter and early spring when increasing light intensity, loss of marsh vegetation, higher salinity, and lower sedimentation rates contribute to optimal conditions for colonization and growth. Algae are immediately available as a food source, as well as provide cover at low tide for benthic invertebrates. In addition, organic removal data have shown that benthic algae provides a constant source of organic material in the estuary.

A survey of marsh vascular plant communities has indicated that the sedge Carex sp. is the dominant intertidal plant on the delta. Studies indicate that the net production of Carex sp. on the Central and East deltas are among the highest reported in the literature.

It has been noted that changes in upland vegetation of the estuary could be associated with elevation above high water, proceeding through a continuum of reed grass, deciduous shrub thickets, Sitka spruce/cottonwood, to a Sitka spruce/broadleaf maple association.

Approximately 96 percent of the annual net primary productivity on the delta has been attributed to Carex sp. while benthic algae are responsible for 4 percent. Carex sp. must be changed by decomposition into detritus before it is generally available to consumers. Therefore, it has been suggested that benthic algae are important to the estuary because they are readily available for consumption, they supply energy for specialized consumers, it is a possible requirement in the diet of some invertebrates, it is an auxiliary source of detritus when the breakdown of Carex sp. is lowest, and it utilizes nutrients regenerated from existing sediments and detritus. The Squamish estuary is a detritus-based removal system with most of the energy input and storage attributable to vascular plants of the tidal marshes.

Studies should be undertaken on the benthic algae and marsh vegetation of the Mamquam delta. Marsh vegetation of the Central and Mamquam deltas should be more completely mapped. Below ground energy flow and the fate of removed organics should be considered in detail through studies of vegetation community functions in the estuary.

Benthic Invertebrate Populations

Distribution and abundance of intertidal benthic invertebrates is primarily a function of salinity regime and distance from the river, and secondarily of elevation and substrate type. Freshwater and estuarine invertebrates were abundant in higher stations on the West and Central deltas. In areas subject to high salinities such as the Mamquam delta and front of the Central delta, estuarine and marine organisms were abundant. It has been noted that both

diversity and abundance varies with habitat. There was seasonal and spatial differences in the types of organisms collected in horizontal plankton tows and the presence of invertebrates in these tows was related to river runoff. Marine plankton has been noted to penetrate the Central basin and Mamquam Channel during winter when fresh water was not widespread.

Eogammarus confervicolus (Amphipoda) are most abundant under sedge rhizomes or algal material, but are widely distributed over the delta. It has been suggested that construction of the training dyke has reduced flushing of amphipods from the central area of the estuary and is, therefore, responsible for their relatively high abundance in this area. Laboratory experiments show growth rates of amphipods are greatest on a diet of benthic algae under conditions simulating spring on the Central delta, and summer on the Mamquam delta. Growth rates are lowest under conditions simulating summer on the West delta. These data emphasize the importance of the Central delta for invertebrate production. Several species of subtidal invertebrates have been observed on the delta front. These include crab, shrimp, nudibranch, and anemone.

The long-term effects of the training wall on the marshes of the central area should be closely monitored. Increased salinity may have a detrimental effect on the Carex sp. of this area. Information on generation time and longevity of Eogammarus confervicolus would be of value in examining how this species is exploited by juvenile salmonids. Studies of freshwater invertebrates inhabiting the river channel between the culverts and the northern boundary of the study area should be undertaken. More detailed studies should be made of the subtidal invertebrates of the delta front.

Fisheries Resources

The Squamish River supports four species of Pacific Salmon; chum, chinook, coho, and pink. The Department of Fisheries and Oceans

estimate that the present salmon resource of the Squamish River totals 572,377 fish. Of this total, 198,093 spawners produce an annual commercial catch of 266,030, a salt water sport catch of 104,369, and an Indian food fishery catch of 3,885 fish. This resource represents an annual commercial net value (1978 prices) of $2,297,935.

The Squamish also supports a major sport fishery primarily centered on steelhead and coho, but which also includes cutthroat trout and Dolly Varden char. The Squamish steelhead fishery is considered one of the finest in the Lower Mainland area and one of the better fisheries in the entire province. An angler effort (based on a five-year average) of 6,343 days/year is expended on a total run of 1,943 steelhead, of which 487 are caught and killed, and 549 caught and released. Escapement of steelhead to the spawning grounds averages 1,456 fish per year. The average number of coho caught by sport fishermen in the Squamish system falls in the range of 800-1,000 fish per year.

The social and economic aspects of the Squamish sport fishery is emphasized by the close proximity of the Greater Vancouver populace. Alteration of habitat could have profound effects on fish populations and, in turn, on a large and important sport fishery.

It has been indicated that the Central basin is the most favourable habitat for juvenile salmonids. The smallest catches of salmon were taken in Mamquam Channel on the east side of Squamish Terminals' fill area. However, 99 percent of herring were caught on the east side of Squamish Terminals. Most salmonid species appear to be seasonally abundant in the estuary coinciding with both juvenile and adult migration periods.

Amphipods and mysids appear to be the major food sources of juvenile salmonids, herring, sculpins, and starry flounders. Other estuarine benthic invertebrates and some insects also serve as food for juvenile salmon and herring. Fish in the outer estuary were found to utilize two separate food sources; marine plankton, and an amphipod/insect complex dependent on algal and sedge production on the delta.

The change in food source, which occurs from April to June, is felt to be due to the decrease in phytoplankton production brought on by the freshet.

Locations used by spawning salmonids in the study area are not well documented. Among those that have been noted are: the slough on the west side of the Squamish River approximately 1.6 km upstream of the delta front, gravel bars in the Squamish River about 0.7 km downstream of the Mamquam River, Loggers Lane Creek (at the head of Mamquam Channel), Monmouth Creek, and the Stawamus and Little Stawamus Rivers.

Enhancement of salmonid stocks has been, and will continue to be undertaken in the Squamish system. Several projects are presently underway or are being considered for the enhancement of steelhead and salmon. These include fry introductions, fish culture facilities, and smolt releases.

Many aspects of fish biology and habitat relationships at the Squamish estuary are poorly understood. Studies to develop accurate species enumeration and periodicity, as well as an understanding of the relationships between habitat units and the fish species which use them, should be undertaken.

Wildlife Resources

Visiting and resident wildlife species are known, but abundance and habitat utilization within the study area are not well understood. Of the marine mammals, harbour seals and killer whales are regular visitors to the estuary. Eight species of furbearers are known to be present in the study area and other species are suspected to occur. Furbearers are likely to be distributed throughout the study area wherever there is suitable habitat. Big game animals utilizing the study area include Columbian blacktail deer, black bear, and cougar. Thirty-four non-game wildlife species in the Orders of shrews, bats, rodents, and hares are believed to inhabit the area.

Species lists suggest that a potential 187 bird species use the Squamish estuary and adjacent water and upland areas. Waterbirds, shorebirds, raptors, songbirds, and upland game birds are the major groups inhabiting the study area. Vegetated foreshore is an important habitat requirement of waterbirds. Vegetation may be eaten directly by birds or may contribute to their food supply indirectly through the detrital food chain. A number of species (notably a large concentration of bald eagles) depend for food seasonally on the carcasses and eggs of salmon within the study area. Water depth is also an important habitat requirement. Generally, the greater the area of intertidal zone and adjacent subtidal zone, the better the habitat for waterfowl.

Many aspects of wildlife biology and habitat relationships at the Squamish estuary are poorly understood. Studies to develop accurate species enumeration and periodicity, as well as an understanding of the relationships between habitat units and the wildlife species which use them, should be undertaken.

Areas Formally Designated or Proposed
for Fish and/or Wildlife Protection

1. A 10.5 hectare municipal reserve leased to the School Board adjacent to the high school is currently used as a nature study area.

2. The Department of Fisheries and Oceans has recommended that all areas of the estuary be protected for conservation except those areas which do not contribute significantly to estuarine productivity. These areas have been defined as:

   - that portion of the Mamquam Channel northeasterly of the public docking site,

   - all areas enclosed by flood control dykes,

   - where dykes are not present, all areas above extreme high tide mark and separated from this demarcation by an adequate site specific green-belt area,

   - shoreline areas on both east and west sides of Howe Sound south of the Squamish River delta.

3. The District of Squamish and Squamish Chamber of Commerce have prepared a brief recommending that areas of the estuary west of the B.C. Rail line serving Squamish Terminals be considered for conservation.

4. The Squamish Estuary Nature Centre Committee (ad hoc.) has prepared a brief recommending a nature centre be located on the Central and East deltas.

Land Use Effects on Aquatic and Terrestrial Habitats

There are four main areas of modification of aquatic habitats in the study area: dykes and training wall, fill and reclamation, dredging, and log storage. Direct alienation, bank modification, salinity and sediment changes, substrate scour or smothering, and shading are potential effects of these land use activities on aquatic habitats.

Terrestrial habitats can be affected detrimentally through general urbanization, the pursuit of recreation, and agriculture. Alienation of habitat, undue disturbance, and competition with domestic animals are potential effects of these land use practices.

There can also be beneficial effects for opportunistic species brought about through land development. Roosting and nesting habitat can be created, additional food sources made available, and agricultural activity can contribute food directly and indirectly as well as provide habitat for some species. Beneficial effects are also the planned result of reserve and conservation areas.

Terrestrial, Intertidal, and Aquatic Habitat Zones

The delineation of habitat zones and classes was made using information from a variety of existing biological and physical studies, and from the interpretation of air photographs. The classification is biophysically based, using vegetation types and substrate as the main criteria for delineating map units.

The estuary has been divided into four main habitat zones; Open Water, Intertidal, Backshore/Lowland, and Upland. These zones are further subdivided into a number of natural units termed habitat classes. These habitat zones and classes, as well as the characteristics of each habitat class, are described in a Habitat Classification Table. In addition, the zones and habitat classes were mapped as to their position in the study area.

Synthesis of Habitat Class Priorities

Each habitat class was assigned a priority rating based on the degree of importance of the habitat to estuarine productivity in general, and estuarine dependent fish and wildlife in particular. Priorities were defined as Critical, Important, Moderate, and Limited. Habitat management guidelines developed for the habitat priorities indicate the acceptability of development in each area, as well as the manner by which proposed developments should be assessed.

Habitat Restoration and Enhancement

The overriding concern of the Habitat Work Group is the continued viability of the estuary through preservation of sufficient estuarine habitat and maintenance of water quality. Considerable direct loss of habitat has occurred over the years, alienating this habitat from estuarine productivity. In addition, certain activities may be degrading the quality of the remaining habitat within the estuary.

There are a host of possible habitat restoration and enhancement opportunities within the Squamish River estuary. Recommendations have been formulated by the Habitat Work Group which consider erosion and water control, industry relocation, dredge spoil and debris removal, revegetation, riparian activity control, and public involvement.

Conclusions and Recommendations

Existing information indicates that the Squamish River estuary is critical to at least certain stages of the life cycles of a number of economically and socially important fish and wildlife species; and contributes significantly to the richness of Howe Sound and the Strait of Georgia.

The fish and wildlife of the Squamish estuary rely to varying degrees on some or all of the major habitat zones within the estuary. Our ability to maintain and perhaps enhance those fish and wildlife resources is contingent upon our ability to conserve and manage what remains of the estuary.

The following recommendations are offered:

1. Adoption of the habitat management guidelines as policies with the management plan.

2. Filling of identified data gaps.

3. Ground truthing of the habitat classification.

4. Assessment and implementation of identified habitat restoration/enhancement opportunities.

5. Implementation of a habitat monitoring program.

GLOSSARY

ALCIDS: birds belonging to the family Alcidae (the Auk family). They have short necks and pointed, stubby or deep and laterally compressed bills. They are the northern counterpart of the penguin family.

ALGAE: a group of mainly aquatic plants, variously one celled, colonial, or filamentous, containing chlorophyll and/or other pigments (especially reds and browns), and having no vascular system.

AMPHIBIANS: cold-blooded vertebrate animals that hatch as gill-breathing larvae (tadpoles) and usually change into lung-breathing adults (e.g. frog, toad, salamander).

AMPHIPOD: one of an order of Crustacea, mostly marine, characterized by having the first and, perhaps, the second thoracic segment fused with the head; the abdomen is not well differentiated from the thorax, and the legs are modified for various functions; the body is laterally compressed.

ANADROMOUS: a form of fish life cycle in which maturity is attained in salt water, and the adults enter fresh water to spawn.

ANNUAL NET PRODUCTIVITY: a quantitative index which describes the amount of organic substance accrued annually by an organism after withdrawal of some of the substance for use in the organism's metabolic processes.

AQUATIC: of, or pertaining to, water.

AVIAN: of, relating to, or derived from birds.

BATHYMETRY: the science of measurement of the depths of oceans seas or lakes. Sometimes refers to the bottom topography of marine or lake systems.

BENTHIC: pertaining to organisms that live in or on the bottom of a sea or lake.

BIOCIDE: a substance that is destructive to biological organisms (e.g. DDT).

BIOMASS: the total weight of living matter in a given area; equivalent to standing crop.

BRACKISH: water having a salinity of less than 17.0 parts per thousand and more than 0.5 parts per thousand.

CARNIVORE: a flesh-eater.

CHIRONOMIDS: true flies belonging to the midge family.

CHLOROPHYTE: green algae; named for the presence of the green pigment chlorophyll.

CLINE: a progressive change or gradient in structure or feature.

COMMUNITY: a naturally occurring group of different organisms inhabiting a common environment, interacting with each other, and relatively independent of other groups, or, an assemblage of closely tied niches.

COPEPOD: any of a large order of usually small marine and freshwater crustaceans. Most species range between about 0.5 to 10 millimetres in length. They often form an important source of food for fish in temperate and subpolar climates, living as they do in the plankton and benthos of marine, estuarine and fresh waters.

CORIOLIS EFFECT: deflection of a body in motion due to the earth's motion.

CRUSTACEAN: any of a large class of mostly aquatic creatures having an outer skeleton; exoskeleton composed of calcium carbonate and chitin, or a form of carbohydrate; it includes shrimps, crabs, wood lice, barnacles, cladocerans, amphipods, isopods, and mysids.

DELTA: the low, nearly flat, alluvial tract of land deposited at or near the mouth of a river, commonly forming a triangular or fan-shaped plain of considerable size, enclosed and crossed by many distributaries of the main river, perhaps extending beyond the general trend of the coast, and resulting from the accumulation (in a wider body of water) of sediment supplied by the river in such quantities that it is not removed by tides, waves, or currents.

DELTA FRONT: a narrow zone where deposition in deltas is most active, consisting of a continuous sheet of sand, and occurring at the effective depth of wave erosion.

DETRITUS: dead organic matter, both plant and animal in origin. Fragments of matter that have been removed - by disintegration, weathering or other processes - from the surface of rocks; a deposit of any of all forms of detritus (adjective - detrital).

DIATOM: one of an algal class (Bacillariophyceae) of microscopic organisms, characterized by thin shells of silica.

DIPTERAN: any of a large order (Diptera - true flies) of insects including the housefly, mosquito, gnat, etc., having one pair of functional membranous wings and usually a vestigial second pair; some species have larval stages that live in fresh water.

ECOSYSTEM: a basic unit in ecology, comprising the organisms that form communities, along with their environment.

EELGRASS: a submerged marine vascular plant that has long narrow leaves, produces seeds and generally grows on a sand or mud substrate in the lower intertidal and upper subtidal zones; e.g., Zostera marina in B.C. coastal waters.

ENTRAINMENT: the transfer of fluid from one water mass to another; occurs if the masses are in motion relative to one another, and results from mixing due to frictional effects at the interface between the masses.

ESCAPEMENT: a statistical term that describes the number of fish that pass unharmed from place to place; indicates the number of salmon adults which survive ocean life and start up a river to the spawning grounds, or the number of juvenile salmon that go to sea after hatching in a stream (usually the former).

ESTUARY: an area of mixing of fresh water and seawater, as at the mouth of a river or stream.

EURYHALINE: able to live in waters of a wide range of salinity.

FAUNA: animal life of a specific region or time.

FOOD CHAIN: the succession of trophic levels through which energy flows in an ecosystem. As an example phytoplankton is eaten by copepods, copepods by fish, and fish by seals.

FOOD WEB: the combined food chains of the community or ecosystem.

FORESHORE: with respect to land use in British Columbia, the land between mean high tide and mean low tide.

FRESHET: a sudden increase or rise in the river flow or level because of melting snow and/or heavy rain.

FRY: young fish, newly hatched, after yolk sac has been used up and active feeding commenced.

FURBEARER: any fox, badger, beaver, marten, fisher, Canada lynx, bobcat, mink, muskrat, land otter, sea otter, racoon, skunk, red squirrel, weasel (ermine), wolverine, wolf, or coyote.

GAME ANIMAL: all big game (mountain sheep and goat, the deer family, bear, cougar, wolf), game birds (grouse, partridge, quail, pheasant, ptarmigan, ducks, geese) and furbearing animals.

GRAVID: heavily-laden with ripe eggs; ready to spawn.

HABITAT: the place where an organism, or a population, lives.

HAUL-OUT SITE: rocks, sandbars, log booms, etc., that harbour seals climb onto to rest and sun. Areas are chosen where the seals can quickly dive into the water should they be disturbed.

HERONRY: heron nesting colony.

HETEROTROPHIC: requiring organic food substances to produce own organic material.

INTERTIDAL ZONE: the area of shore bounded by the levels of high and low tide.

INVERTEBRATE: an animal not having a backbone.

ISOPOD: any of an order of crustaceans, mostly aquatic, with a flat, oval body and seven pairs of walking legs of similar size and form, each pair attached to a segment of the thorax.

LARVA: an organism at some pre-adult stage of development, incapable of reproduction and often morphologically and ecologically distinct from the adult stage.

MAMMAL: an animal having hair and mammary glands.

MARSH: a tract of soft, wet land, characterized by growth of plants such as sedges and grasses; a saltmarsh is subject to overflow by salt water, as by tidal action.

MARINE: of, or pertaining to, the sea.

MIGRATORY: to pass, usually periodically, from one region or climate to another for purposes of feeding, breeding, etc.

MOLLUSCS: an invertebrate animal with a soft, pulpy body and usually a hard outer shell (E.G. oyster, clam, snail).

MYSIDS:	small, shrimp-like crustaceans, most of which are marine although a few occur in estuarine and fresh waters. They are mostly carnivorous, but take vegetable matter in the course of feeding.
NET GROWTH EFFICIENCY:	a quantitative index which describes the ability of an organism to utilize food for growth, as opposed to respiration.
NUDIBRANCH;	a group of snail-like molluscs lacking shells; also known as "sea slugs".
PAN:	a low depressional area within a marsh which retains water when the tide falls. The combination of increased soil salinity due to evaporation and permanent water logging restricts and inhibits vegetative colonization.
PASSERINE:	refers to a large group of birds (Passeriformes) which perch, with the aid of the large first toe which is directed backwards, while the other three remain forward.
PHAEOPHYTE:	brown algae.
PHYTOPLANKTON:	plant life, mostly microscopic, found floating or drifting in the oceans or large bodies of fresh water; forms the base of most aquatic food chains as the main primary producers.
PLANKTON:	plant and animal life, mostly microscopic, drifting or floating freely in the water column of oceans and bodies of fresh water.
POLYCHAETE:	any of a class of mostly marine, segmented worms; usually having a pair of fleshy leg-like appendages covered with setae, on most segments, and usually having a well-developed, distinct head.
PRIMARY PRODUCTIVITY:	the rate at which energy is stored by photosynthesizing organisms (mainly green plants) in the form of organic substances.
PUPAE:	an intermediate stage of a metamorphic organism.
RAPTORS:	birds of prey, usually having a strong, notched beak and sharp talons (e.g. eagles, hawks, owls, vultures).
REPTILES:	a class of cold-blooded, air-breathing vertebrate animals that crawl or move on their bellies (as a snake) or on small, short legs (as a lizard).
RHIZOMES:	horizontal underground stems.
RUN-OFF:	the portion of rainfall which ultimately reaches the streams; it consists of the water which flows off the surface, instead of sinking into the ground, together with some of the water which originally sank into the ground and joined later in the streams.

SALINITY:	a measure of the quantity of dissolved salts in seawater. It is formally defined as the total amount of dissolved solids in seawater - in parts per thousand by weight - when all the carbonate has been converted to oxide, the bromide and iodide replaced by chloride, and all organic matter is completely oxidized.
SALMONID:	all fish belonging to the family Salmonidae, which includes salmon, trout, char, and related species.
SEDGE:	any of a family of grasslike plants often found on wet ground or in water, usually having triangular solid stems, three rows of narrow, pointed leaves, and minute flowers borne on spikelets.
SEDIMENTATION:	the action or process of depositing sediment.
SHOREBIRD:	any of a number of birds that feed (usually by wading) or nest on the shores of oceans, rivers, etc.; examples are sandpipers, snipes, etc.
SMOLT:	in salmonids, the life stage older than a fry and physiologically adapted to leave fresh water and enter salt water.
SPAWN (verb):	to produce or deposit eggs - usually used in reference to aquatic animals such as fish, or crustaceans. (noun): eggs of the above.
STANDING CROP:	the amount of living material in a given area; equivalent to biomass.
SUBTIDAL:	below the lowest low tide line.
TROPHIC LEVEL:	a "food level" in an ecosystem. For example, a seaweed is at one trophic level, the amphipod that eats the seaweed is at the next highest trophic level, and so on.
UNGULATE:	belonging to a group of mammals, all of which have cloven hooves and are ruminants.
VASCULAR PLANTS:	a plant having a specialized conducting system that includes xylem and phloem.
VERNAL:	relating to, or appearing, or occurring in, the spring.
VERTEBRATE:	an animal possessing a backbone.
ZOOPLANKTON:	animal life, usually microscopic, found floating or drifting in the water column of oceans or bodies of fresh water; form the bulk of the primary consumer link in aquatic food chains.

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APPENDIX A: SUPPLEMENTARY TABULAR DATA

A.1 Total numbers of birds seen at the Squamish River estuary in each month from October 1972 to May 1973.

A.2 Mean numbers of birds seen and ranges in numbers of birds seen each month at the Squamish River estuary, October 1972 to May 1973.

A.3 Numbers of birds seen at the Squamish River estuary, October 1972 to May 1973 in each of 13 sub-areas of the estuary.

A.1 Total Numbers of Birds seen at the Squamish River estuary in each month from October, 1972 to May, 1973.

Species	Total Numbers of Birds seen each Month									
	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May		Σ
Loon										
Common		29	39			3	2	3		76
Red-Throated				13	8	19	1			41
Loon Species	8			59	11	28	2	1		109
Total Loons	8	29	39	72	19	50	5	4		226
Grebe										
Red-Necked	8	4	1	3	23	8	12	8		67
Horned	297	454	329	280	103	262	240	30		1995
Western	1247	2358	1319	451	1202	1784	666	472		9499
Pied-Billed		5	1	5						11
Grebe Species	275	11	9	117	26	57	3			598
Total Grebes	1927	2832	1659	856	1354	2111	921	510		12170
Cormorant										
Double-Crested		3			141	196	6	4		350
Pelagic	1							1		2
Cormorant Species	47	98	206	350			1			702
Total Cormorants	48	101	206	350	141	196	7	5		1054
Heron										
Great Blue	26	28	4	5	24	32	19	12		150
Green	1									1
Total Herons	27	28	4	5	24	32	19	12		151
Swan Species		1	17	32	19	6				75
Canada Goose			7							7
Dabbling Ducks										
Mallard	219	496	288	344	313	773	968	103		3504
Pintail	119	79	82	100	246	390	273	61		1350
Teal										
Green-Winged	235	33	27	5		70	100	49		519
Cinnamon								13		13
American Wigeon	123	11		1	4	14	72	94		319
Northern Shoveler	6						5	18		29
Wood Duck							1	2		3
Dabbling Duck Species	47	15	5	9	27	4		23		130
Total Dabbling Ducks	749	634	402	459	590	1251	1419	363		5867
Diving Ducks										
Canvasback	3						7			10
Scaup Species		1	13	119	96	141	303	171		844
Goldeneye										
Common		108	193	355	370	539	426	153		2294
Barrow's	13	7	2	66		12	36	4		140
Goldeneye Species	2	154	615	229	154	295	75	13		1537
Bufflehead	85	290	400	487	243	457	470	87		2519
Oldsquaw			3	2		1	3			9
Scoter										
White-Winged								1		1
Surf						11	3	5		19
Scoter Species								14		14
Ruddy Duck							1			1
Merganser										
Hooded	9	29	2	6	4	13	14			77
Common	44	54	227	440	101	156	45	39		1106
Red-Breasted		2	11	202	75	37	31	2		360
Merganser Species	58	32	25	63	68	32	5	8		291
Diving Duck Species	41	1	12	14	23	5	15			111
Total Diving Ducks	255	678	1453	2183	1134	1699	1439	497		9333
Raptors										
Red-Tailed Hawk		1	1							2
Golden Eagle						1				1
Bald Eagle		4	1	50	69	47	3	1		175
Marsh Hawk	5	3								8
American Kestrel							1			1
Raptor Species	1	1	1				1			4
Total Raptors	6	9	3	50	69	48	5	1		191

A.1 (cont'd)

Total Numbers of Birds seen each Month

Species	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May		Σ
American Coot	1									1
Shorebirds										
Killdeer	12	7	7	5	3	5	21			60
Black-Bellied Plover	3									3
Common Snipe	1						1			2
Yellowleg Species							3			3
Least Sandpiper								16		16
Dowitcher Species	128	7								135
Western Sandpiper		78	2	2				1		83
Shorebird Species	7	51			2			12		72
Total Shorebirds	151	143	9	7	5	5	25	29		374
Gull Species	1144	864	2456	3723	516	428	169	176		8746
Alcids										
Common Murre						3	2			5
Marbled Murrelet	5	32	20	18	14	48	4	12		153
Total Alcids	5	32	20	18	14	51	6	12		158
Belted Kingfisher	8	18	9	4	1	3				43
Common Flicker	1	1	1	1						4
Passerines										
Horned Lark								7		9
Swallow Species			2					2		2
Steller's Jay										1
Common Raven	1				2					2
Northwestern Crow	89	166	154	390	446	558	90	73		1966
Clarke's Nutcracker	1									1
American Robin						1	1	2		9
Varied Thrush							5			5
Mountain Bluebird							4			4
Water Pipit								6		6
Starling	90				100	1218	755	41		2204
Townsend's Warbler	1									1
Red-Winged Blackbird					26	52	20	15		113
Rufous-Sided Towhee	1									1
Red Crossbill	14									14
Song Sparrow							5			5
Passerine Species	6			30		140	2			178
Total Passerines	203	166	156	420	579	1969	882	146		4516

A.2 Mean numbers of birds seen and ranges in numbers of birds seen each month at the Squamish River e.tuary, October, 1972 to May, 1973.

Species		Numbers of Birds Seen: Each Month								During Entire Study	
		Oct. n=7	Nov. n=7	Dec. n=6	Jan. n=7	Feb. n=3	Mar. n=5	Apr. n=4	May n=3	$\bar{x}$ n=42	range
Loon Common	$\bar{x}$		4.1	6.3			0.6	0.5	1.0	1.8	0-15
	r		0-9	2-15			0-2	0-2	0-2		
Red-Throated	$\bar{x}$				1.9	2.7	3.8	0.3		1.0	0-12
	r				0-12	2-3	0-7	0-1			
Loon Species	$\bar{x}$	1.1			8.4	3.7	5.6	0.5	0.3	2.6	0-23
	r	0-6			1-23	2-5	1-14	0-1	0-1		
Total Loons	$\bar{x}$	1.1	4.1	6.3	10.3	6.3	10.0	1.3	1.3	5.4	0-35
	r	0-6	0-9	2-15	1-35	5-8	2-19	0-2	0-3		
Grebe Red-Necked	$\bar{x}$	1.1	0.6	0.2	0.4	7.7	1.6	3.0	2.7	1.6	0-23
	r	0-3	0-2	0-1	0-1	0-23	1-3	0-7	0-7		
Horned	$\bar{x}$	42.4	64.9	54.8	40.0	34.3	52.4	60.0	10.0	47.5	2-109
	r	8-84	27-105	13-88	2-109	19-65	22-74	39-82	4-18		
Western	$\bar{x}$	178.1	336.9	219.8	64.4	400.7	356.8	166.5	157.3	226.2	0-772
	r	0-500	0-600	5-772	0-230	352-450	16-625	1-337	134-170		
Pied-Billed	$\bar{x}$		0.7	0.2	0.7					0.3	0-3
	r		0-2	0-1	0-3						
Grebe Species	$\bar{x}$	53.6	1.6	1.5	16.7	8.7	11.4	0.8		14.2	0-320
	r	0-320	0-8	0-5	2-36	3-15	0-46	0-2			
Total Grebes	$\bar{x}$	275.3	404.6	276.5	122.3	451.3	422.2	230.3	170.0	289.8	9-863
	r	9-528	37-705	39-863	37-293	386-500	88-670	44-423	139-205		
Cormorant Double-Crested	$\bar{x}$		0.4			47.0	39.2	1.5	1.3	8.3	0-70
	r		0-3			35-53	20-70	0-4	0-3		
Pelagic	$\bar{x}$	0.1							0.3	0.0	0-1
	r	0-1							0-1		
Cormorant Species	$\bar{x}$	6.7	14.0	34.3	50.0			0.3		16.7	0-190
	r	0-12	3-25	6-140	10-82			0-1			
Total Cormorants	$\bar{x}$	6.9	14.4	34.3	50.0	47.0	39.2	1.8	1.7	25.1	0-190
	r	0-13	3-25	6-140	10-82	35-53	20-70	0-4	1-3		
Heron Great Blue	$\bar{x}$	3.7	4.0	0.7	0.7	8.0	6.4	4.8	4.0	3.6	0-12
	r	1-7	2-6	0-2	0-2	3-11	0-12	2-7	3-5		
Green	$\bar{x}$	0.1								0.0	0-1
	r	0-1									
Total Herons	$\bar{x}$	3.9	4.0	0.7	0.7	8.0	6.4	4.8	4.0	3.6	0-13
	r	1-7	2-6	0-2	0-2	3-11	0-13	2-7	3-5		
Swan Species	$\bar{x}$		0.1	2.8	4.6	6.3	1.2			1.8	0-8
	r		0-1	0-7	0-8	6-7	0-5				
Canada Goose	$\bar{x}$			1.2						0.2	0-7
	r			0-7							
Dabbling Ducks Mallard	$\bar{x}$	31.3	70.9	48.0	49.1	104.3	134.6	242.0	34.3	83.4	0-312
	r	0-92	17-135	5-85	14-121	73-121	104-188	134-312	24-54		
Pintail	$\bar{x}$	17.0	11.3	13.7	14.3	82.0	78.0	68.3	20.3	32.1	0-138
	r	1-60	0-23	0-50	0-38	66-101	17-113	25-138	1-52		
Teal Green-Winged	$\bar{x}$	33.6	4.7	4.5	0.7		14.0	25.0	16.3	12.4	0-79
	r	4-79	0-15	0-13	0-2		0-40	0-77	2-32		
Cinnamon	$\bar{x}$								4.3	0.3	1-6
	r								1-6		
American Wigeon	$\bar{x}$	17.6	1.6		0.1	1.3	2.8	18.0	34.6	7.6	0-96
	r	0-96	0-11		0-1	0-4	0-6	6-40	1-89		
Northern Shoveler	$\bar{x}$	0.9						1.3	6.0	0.7	0-18
	r	0-2						0-5	0-18		
Wood Duck	$\bar{x}$							0.3	0.3	0.1	0-2
	r							0-1	0-2		
Dabbling Duck Species	$\bar{x}$	6.9	2.1	0.8	1.3	9.0	0.8		7.7	3.1	0-27
	r	0-17	0-9	0-2	0-6	0-27	0-2		0-23		
Total Dabbling Ducks	$\bar{x}$	109.0	90.6	67.0	65.6	196.7	230.2	334.8	121.0	139.7	6-316
	r	25-265	22-196	6-196	15-156	139-249	199-316	181-516	42-231		
Diving Ducks Canvasback	$\bar{x}$	0.4						1.8		0.2	0-7
	r	0-2						0-7			
Scaup Species	$\bar{x}$		0.1	2.2	17.0	32.0	28.2	75.8	37.0	20.1	0-119
	r		0-1	0-5	10-23	29-38	21-36	38-119	3-95		
Goldeneye Common	$\bar{x}$		15.4	23.8	99.3	123.3	107.8	106.5	51.0	54.6	0-249
	r		0-39	0-90	0-229	43-174	54-133	27-213	0-153		

Numbers of Birds Seen

Species		Each Month								During Entire Study	
		Oct. n=7	Nov. n=7	Dec. n=6	Jan. n=7	Feb. n=3	Mar. n=5	Apr. n=4	May n=3	$\bar{x}$ n=42	range
Barrow's	$\bar{x}$	1.9	1.0	0.3	9.4		2.4	9.0	1.3	3.3	0-58
	r	0-12	0-3	0-2	0-58		0-12	0-20	0-2		
Goldeneye Species	$\bar{x}$	0.3	22.0	102.5	32.7	51.3	59.0	18.8	4.3	36.6	0-193
	r	0-2	1-58	17-191	10-54	4-104	14-193	5-33	0-9		
Bufflehead	$\bar{x}$	12.1	41.4	66.7	69.6	81.0	91.4	117.5	29.0	60.0	0-198
	r	0-31	23-55	44-82	53-83	64-104	66-113	57-198	0-59		
Oldsquaw	$\bar{x}$			0.5	0.3		0.2	0.8		0.2	0-3
	r			0-2	0-2		0-1	0-3			
Scoter White-Winged	$\bar{x}$								0.3	0.0	0-1
	r								0-1		
Surf	$\bar{x}$						2.2	0.8	1.7	0.5	0-9
	r						0-9	0-3	0-5		
Scoter Species	$\bar{x}$								4.7	0.3	0-8
	r								0-8		
Ruddy Duck	$\bar{x}$							0.3		0.0	0-1
	r							0-1			
Merganser Hooded	$\bar{x}$	1.3	4.1	0.3	0.9	1.3	2.6	3.5		1.8	0-12
	r	0-4	0-12	0-2	0-2	0-4	0-4	0-11			
Common	$\bar{x}$	6.3	7.7	37.8	62.9	33.7	31.2	11.3	13.0	26.3	0-227
	r	0-16	0-20	0-227	13-129	13-62	24-42	3-19	8-20		
Red-Breasted	$\bar{x}$		0.3	1.8	28.9	25.0	7.4	7.8	0.7	8.6	0-56
	r		0-2	0-9	0-56	12-39	4-12	3-14	0-2		
Merganser Species	$\bar{x}$	8.3	4.6	4.2	9.0	22.7	6.4	1.3	2.7	6.9	0-50
	r	0-29	0-16	0-6	0-36	2-50	1-10	0-3	1-6		
Diving Duck Species	$\bar{x}$	5.9	0.1	2.0	2.0	7.7	1.0	3.8		2.6	0-30
	r	0-30	0-1	0-7	0-5	0-19	0-5	0-13			
Total Diving Ducks	$\bar{x}$	36.4	96.9	242.2	311.9	378.0	334.8	358.5	168.7	222.2	5-544
	r	5-70	49-120	164-421	163-544	345-396	302-416	281-517	33-346		
Raptors Red-Tailed Hawk	$\bar{x}$		0.1	0.2						0.0	0-1
	r		0-1	0-1							
Golden Eagle	$\bar{x}$						0.2			0.0	0-1
	r						0-1				
Bald Eagle	$\bar{x}$		0.6	0.2	7.1	23.0	9.4	0.8	0.3	4.2	0-33
	r		0-2	0-1	0-33	4-53	4-20	0-2	0-1		
Marsh Hawk	$\bar{x}$	0.7	0.4							0.2	0-2
	r	0-1	0-2								
American Kestrel	$\bar{x}$							0.3		0.0	0-1
	r							0-1			
Raptor Species	$\bar{x}$	0.1	0.1	0.2				0.3		0.1	0-1
	r	0-1	0-1	0-1				0-1			
Total Raptors	$\bar{x}$	0.9	1.3	0.5	7.1	23.0	9.6	1.3	0.3	4.5	0-53
	r	0-1	0-4	0-1	0-33	4-53	4-20	0-3	0-1		
American Coot	$\bar{x}$	0.1								0.0	0-1
	r	0-1									
Shorebirds Killdeer	$\bar{x}$	1.7	1.0	1.2	0.7	1.0	1.0	5.3		1.4	0-16
	r	0-4	0-4	0-6	0-2	0-2	0-3	1-16			
Black-Bellied Plover	$\bar{x}$	0.4								0.1	0-1
	r	0-1									
Common Snipe	$\bar{x}$	0.1						0.3		0.0	0-1
	r	0-1						0-1			
Yellowleg Species	$\bar{x}$							0.8		0.1	0-3
	r							0-3			
Least Sandpiper	$\bar{x}$								5.3	0.4	0-16
	r								0-16		
Dowitcher Species	$\bar{x}$	18.3	1.0							3.2	0-38
	r	0-38	0-7								
Western Sandpiper	$\bar{x}$		11.1	0.3	0.3				0.3	2.0	0-78
	r		0-78	0-2	0-2				0-1		
Shorebird Species	$\bar{x}$	1.0	7.3			0.7			4.0	1.7	0-50
	r	0-3	0-50			0-2			0-10		
Total Shorebirds	$\bar{x}$	21.6	20.4	1.5	1.0	1.7	1.0	6.5	9.7	8.9	0-135
	r	1-38	0-135	0-8	0-4	1-2	0-3	2-13	0-27		

Numbers of Birds Seen

Species		Each Month								During Entire Study	
		Oct. n=7	Nov. n=7	Dec. n=6	Jan. n=7	Feb. n=3	Mar. n=5	Apr. n=4	May n=3	$\bar{x}$ n=42	range
Gull Species	$\bar{x}$	166.3	123.4	409.3	367.6	175.0	83.6	42.3	58.7	232.0	14-1118
	r	25-328	20-238	121-1118	239-1093	163-180	39-123	17-76	13-104		
Alcids											
Common Murre	$\bar{x}$						0.6	0.5		0.1	0-2
	r						0-1	0-2			
Marbled Murrelet	$\bar{x}$	0.7	4.6	3.3	2.6	4.7	9.6	1.0	4.0	3.6	0-31
	r	0-5	0-14	0-12	0-13	0-8	1-31	0-4	1-9		
Total Alcids	$\bar{x}$	0.7	4.6	3.3	2.6	4.7	10.2	1.5	4.0	3.8	0-31
	r	0-5	0-14	0-12	0-13	0-8	2-31	0-6	1-9		
Belted Kingfisher	$\bar{x}$	1.1	2.6	1.5	0.6	0.3	0.6			1.0	0-4
	r	0-4	2-3	0-3	0-2	0-1	0-2				
Common Flicker	$\bar{x}$	0.1	0.1	0.2	0.1					0.1	0-1
	r	0-1	0-1	0-1	0-1						
Passerines											
Horned Lark	$\bar{x}$			0.3					2.3	0.2	0-7
	r			0-2					0-7		
Swallow Species	$\bar{x}$								0.7	0.0	0-2
	r								0-2		
Steller's Jay	$\bar{x}$	0.1								0.0	0-1
	r	0-1									
Common Raven	$\bar{x}$					0.7				0.0	0-2
	r					0-2					
Northwestern Crow	$\bar{x}$	12.7	23.7	25.7	55.7	148.7	111.6	22.5	29.3	46.8	0-296
	r	0-30	0-62	1-67	9-210	30-262	15-296	10-44	6-51		
Clarke's Nutcracker	$\bar{x}$	0.1								0.0	0-1
	r	0-1									
American Robin	$\bar{x}$						0.2	0.3	0.7	0.1	0-2
	r						0-1	0-1	0-2		
Varied Thrush	$\bar{x}$							1.3		0.1	0-5
	r							0-5			
Mountain Bluebird	$\bar{x}$							1.0		0.1	0-4
	r							0-4			
Water Pipit	$\bar{x}$								2.0	0.1	0-6
	r								0-6		
Starling	$\bar{x}$	12.9				33.3	243.6	188.8	13.7	52.5	0-925
	r	0-30				0-100	0-925	0-500	0-26		
Townsend's Warbler	$\bar{x}$	0.1								0.0	0-1
	r	0-1									
Red-Winged Blackbird	$\bar{x}$					8.7	10.4	5.0	5.0	2.7	0-45
	r					0-26	0-45	0-15	0-12		
Rufous-Sided Towhee	$\bar{x}$	0.1								0.0	0-1
	r	0-1									
Red Crossbill	$\bar{x}$	2.0								0.3	0-12
	r	0-12									
Song Sparrow	$\bar{x}$							1.3		0.1	0-3
	r							0-3			
Passerine Species	$\bar{x}$	0.9			4.3		28.0	0.5		4.2	0-140
	r	0-3			0-30		0-140	0-2			
Total Passerines	$\bar{x}$	29.0	23.7	36.0	68.0	191.3	393.8	220.5	48.7	107.5	0-1221
	r	0-51	0-62	1-67	9-210	30-282	44-1221	10-537	23-69		

A.3 Numbers of birds seen at the Squamish River estuary, October 1972 to May 1973 in each of 13 sub-areas of the estuary.

Species	Numbers of birds seen in each sub-area*														
	BP	EM	NF	EC	CP	DS	EF	CC	SR	WD	OE	TD	MC		Σ
Loon															
Common				6				11	2		57				76
Red-Throated								12			29				41
Loon Species					3			23	2		79		2		109
Total Loons				6	3			46	4		165		2		226
Grebe															
Red-Necked					3			13	1		43		2		67
Horned	2	10		98	108			866	225	6	677		23		1995
Western				180				23	51		9236		9		9499
Pied-Billed		1			5			5							11
Grebe Species		1		18				89	5		473		12		598
Total Grebes	2	12		276	116			1001	282	6	10,429		46		12,730
Cormorant															
Double-Crested				48	4			46	86		23		143		350
Pelagic											2				2
Cormorant Species				236	1		12	139	24	3	103		189		708
Total Cormorants				284	5		12	130	110	3	128		332		1054
Heron															
Great Blue	14	89	3	1	3	1	16	17	2	3			1		150
Green	1														1
Total Herons	15	89	3	1	3	1	16	17	2	3			1		151
Swan Species		2				51		13	7				2		75
Canada Goose										7					7
Dabbling Ducks															
Mallard	70	1354	28	44	2	117	389	235	49	1165			1		3504
Pintail	49	821	30			27	66	34	68	250	5				1350
Teal															
Green-Winged	80	177	23		2	77	19	89	9	41					519
Cinnamon		13													13
American Wigeon	45	78	4	32	3	17	21	109		10					319
Northern Shoveler	4	1					4	19		1					29
Wood Duck		1	2												3
Dabbling Duck Species	2	49	18			5	3	38	6	7	2				130
Total Dabbling Ducks	250	2499	109	76	7	293	502	374	132	1474	7		1		5867
Diving Ducks															
Canvasback		1						9							10
Scaup Species	165	45		77			5	508			38		6		844
Goldeneye															
Common	6	10	5	176	39		3	641	1041	113	164		96		2294
Barrow's					6	2		39	91	2					140
Goldeneye Species	38	56	8	23	25	1	27	310	664	175	66		144		1537
Bufflehead	245	394	3	79	127	101	77	888	161	237	17		170		2519
Oldsquaw						1		6	1				1		9
Scoter															
White-Winged								1							1
Surf				8				11							19
Scoter Species											14				14
Ruddy Duck								1							1
Merganser															
Hooded	8	47	2		7	4	1	4	2	2					77
Common	18	17	3	49	12		9	45	132	82	22		717		1106
Red-Breasted				1				44	128	35	138		14		360
Merganser Species	5	15		8	19		2	63	81	7	71		20		291
Diving Duck Species		5		9		4	30	41		1	21				111
Total Diving Ducks	485	570	21	430	235	113	154	2611	2301	674	351		1168		9333
Raptors															
Red-Tailed Hawk							1		1						2
Golden Eagle									1						1
Bald Eagle		1		1	16	2	10	15	103	23	3		1		175
Marsh Hawk	2	2	2				1			1					8
American Kestrel					1										1
Raptor Species		1	1				1	1							4
Total Raptors	2	4	3	1	17	2	13	16	105	24	3		1		191

*Legend on next page.

Numbers of birds seen in each sub-area

Species	BP	EM	NF	EC	CP	DS	EF	CC	SR	WD	OE	TD	MC		Σ
American Coot								1							1
Shorebirds															
Killdeer	20	17		4		3	4					3	9		60
Black-Bellied Plover	1	2													3
Common Snipe		1								1					2
Yellowleg Species		3													3
Least Sandpiper	16														16
Dowitcher Species	90	45													135
Western Sandpiper	1	4		18				60							83
Shorebird Species	5	13		50		2		2							72
Total Shorebirds	133	85		72		5	4	62		1		3	9		374
Gull Species	88	716	3	242	7		56	1491	849	737	1764	2930	1366		9446
Alcids															
Common Murre										3	2				5
Marbled Murrelet				9							144				153
Total Alcids				9						3	146				158
Belted Kingfisher	6	19		3	2	1	3	3	1	2			8		47
Common Flicker	1	2	1												4
Passerines															
Horned Lark		7				2									9
Swallow Species		2													2
Steller's Jay			1												1
Common Raven					2										2
Northwestern Crow	137	281	92	53	55	1	107	135	81	843	5	44	132		1966
Clarke's Nutcracker					1										1
American Robin	1	1								2					4
Varied Thrush					5										5
Mountain Bluebird	1	2		1											4
Water Pipit		6													6
Starling	100	990	1	43			335			700			15		2204
Townsend's Warbler			1												1
Red-Winged Blackbird	1		24	1			9		40	38					113
Rufous-Sided Towhee			1												1
Red Crossbill			12				2								14
Song Sparrow			2										3		5
Passerine Species	42	101					2			30		3			178
Total Passerines	282	1290	134	98	63	3	935	135	121	1613	5	47	150		4516

LEGEND

BP	Bridge Pond	CC	Central Channel
EM	East Marsh	SR	Squamish River
NF	North Field	WD	West Delta
EC	East Channel	OE	Outer Estuary
CP	Culvert Ponds	TD	Training Dyke
DS	Dyked Stream	MC	Mamquam Channel
EF	East of Fill		

APPENDIX B: SUPPLEMENTARY FIGURES

B.1 Numbers of goldeneye seen at the Squamish River estuary October 1972 to May 1973

B.2 Numbers of bufflehead seen at the Squamish River estuary October 1972 to May 1973

B.3 Numbers of mergansers seen at the Squamish River estuary October 1972 to May 1973

B.4 Numbers of scaup seen at the Squamish River estuary October 1972 to May 1973

B.5 Sub-areas of the Squamish study area, C.W.S. bird studies, 1972-73

B.6 Numbers of mallards seen at the Squamish River estuary October 1972 to May 1973

B.7 Numbers of pintail seen at the Squamish River estuary October 1972 to May 1973

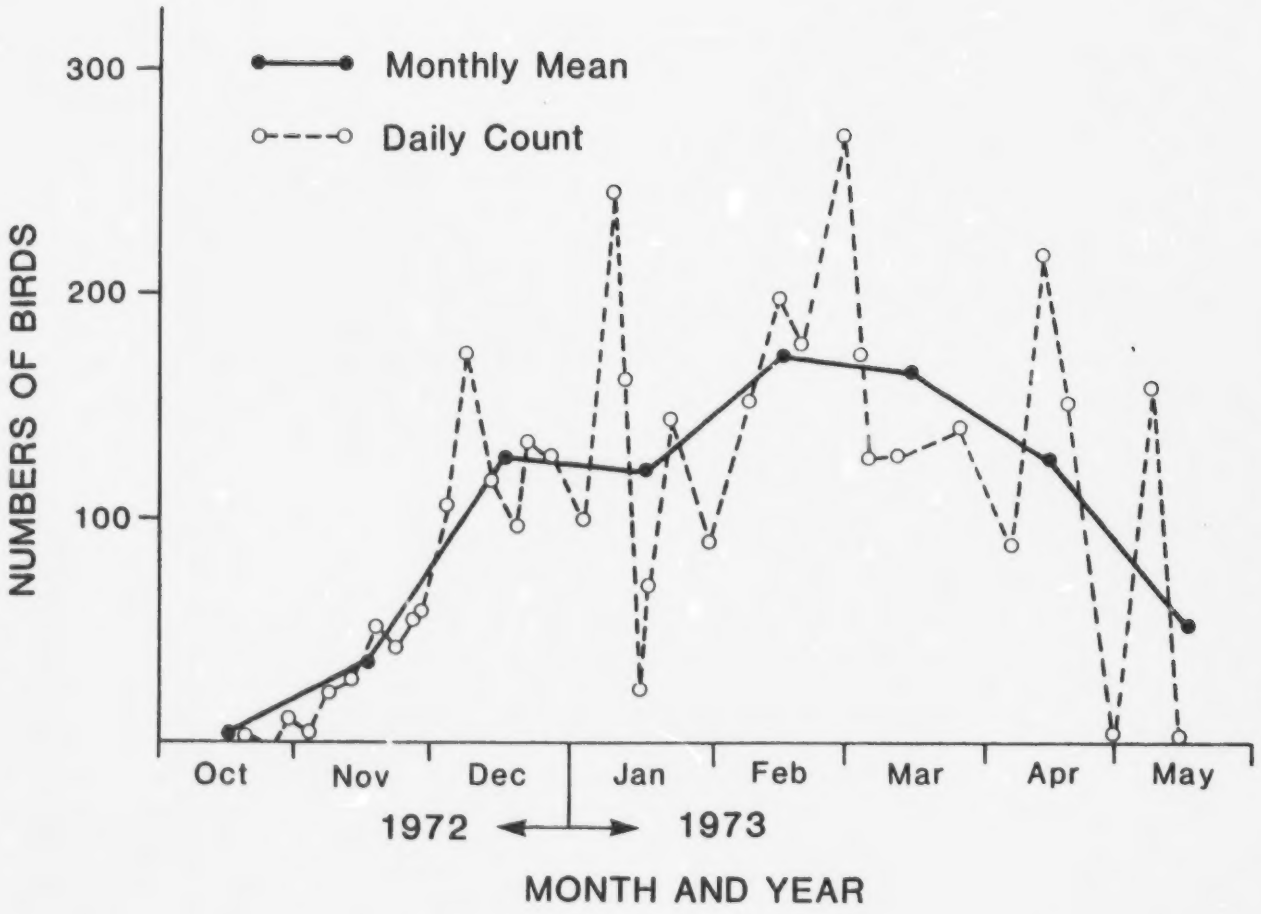
B.8 Mean daily temperature (^{o}C) at Brittania Beach October 1972 to May 1973

B.9 Numbers of green-winged teal seen at the Squamish River estuary October 1972 to May 1973

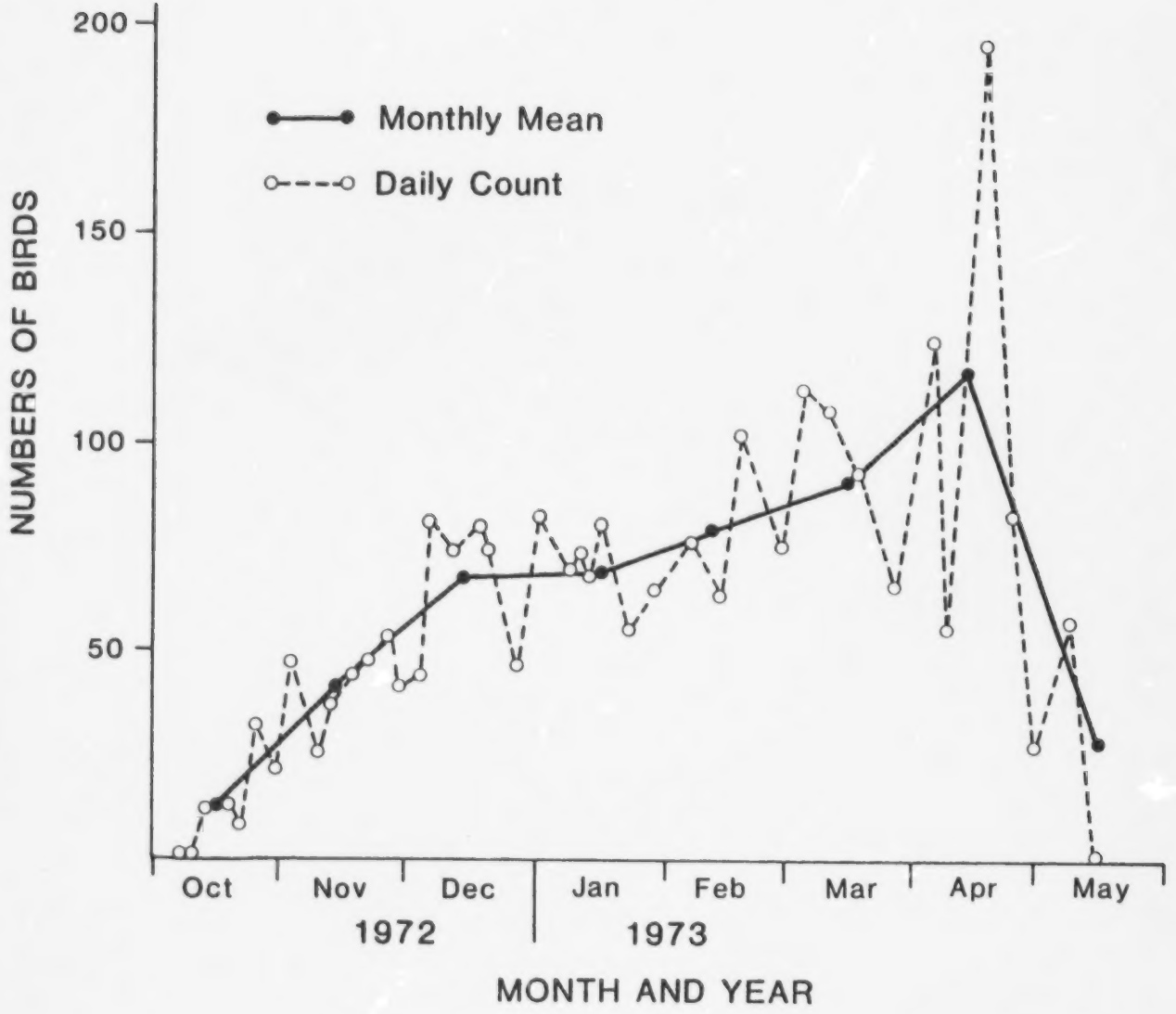
B.10 Numbers of American wigeon seen at the Squamish River estuary October 1972 to May 1973

B.11 Numbers of western grebes seen at the Squamish River estuary October 1972 to May 1973

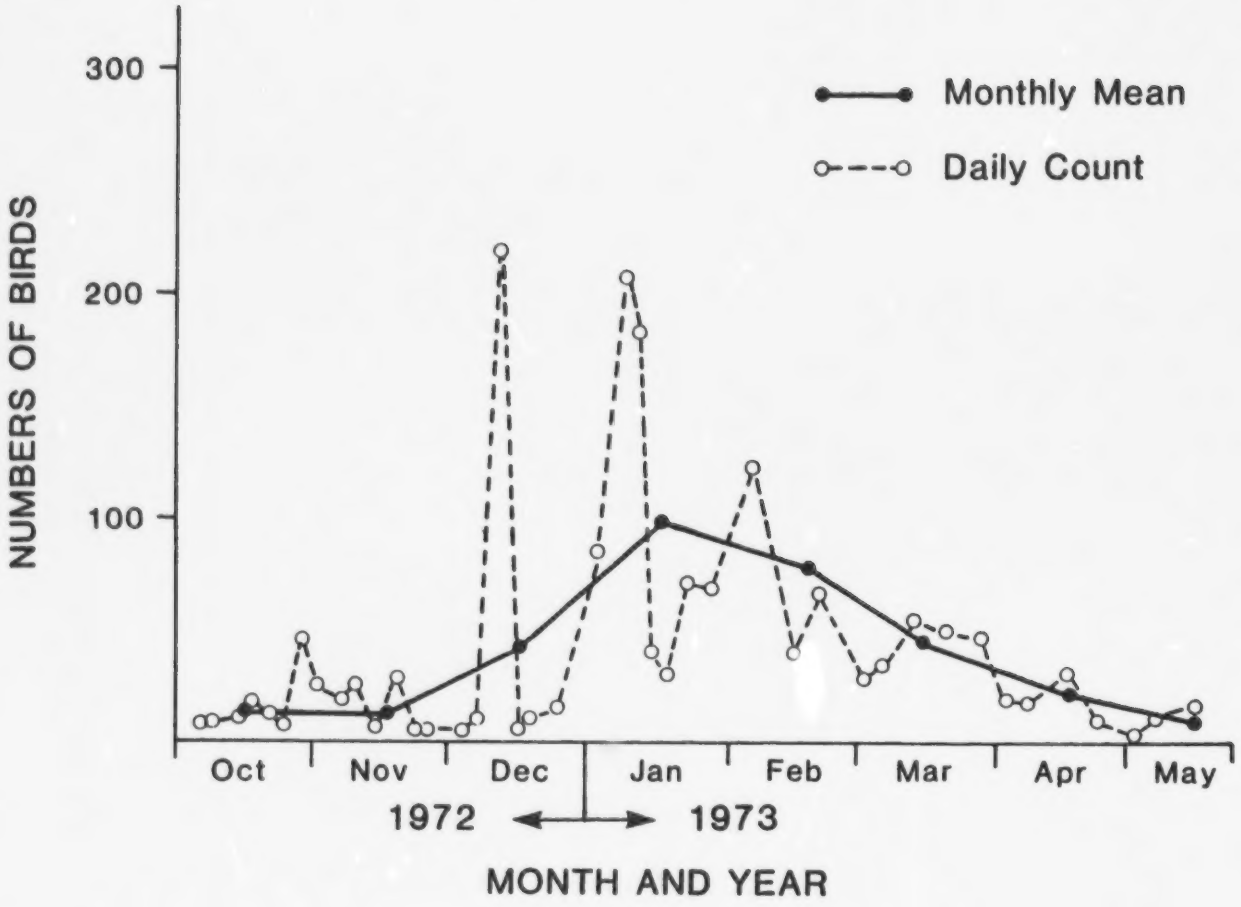
B.12 Numbers of horned grebes seen at the Squamish River estuary October 1972 to May 1973



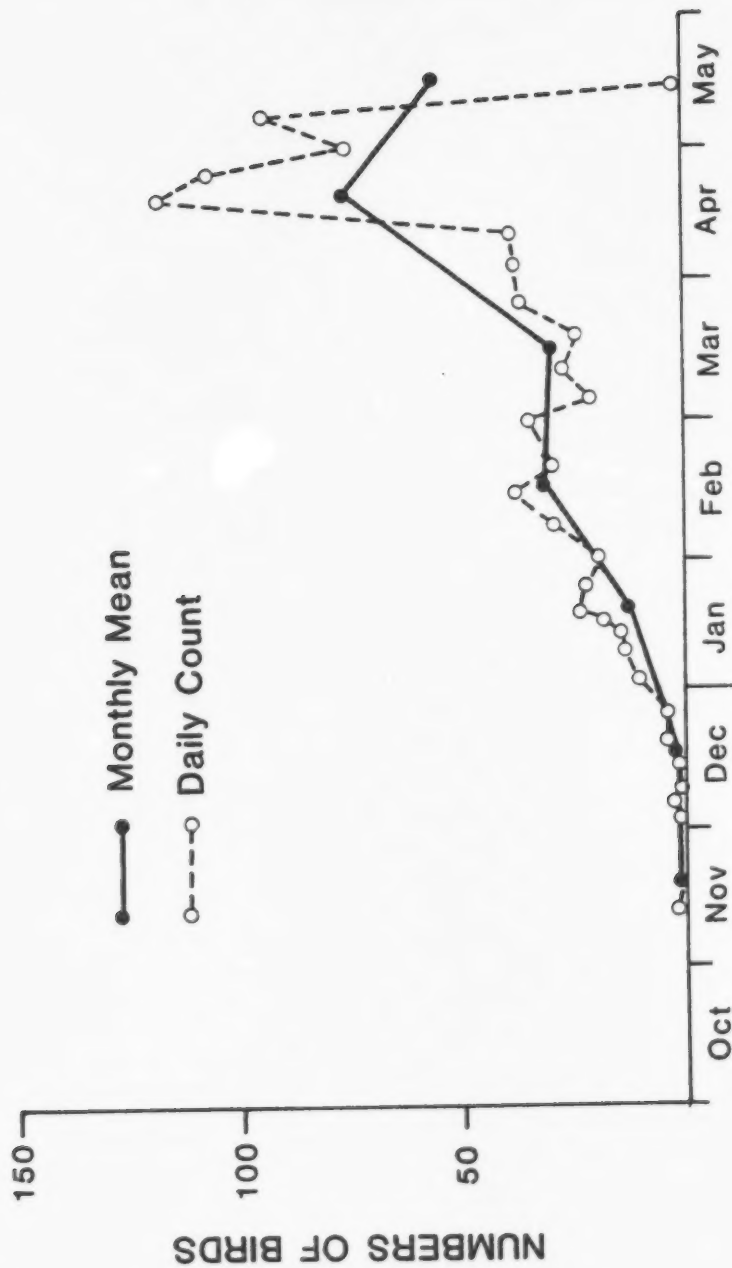
B.1 Numbers of goldeneye seen at the Squamish River estuary October 1972 to May 1973



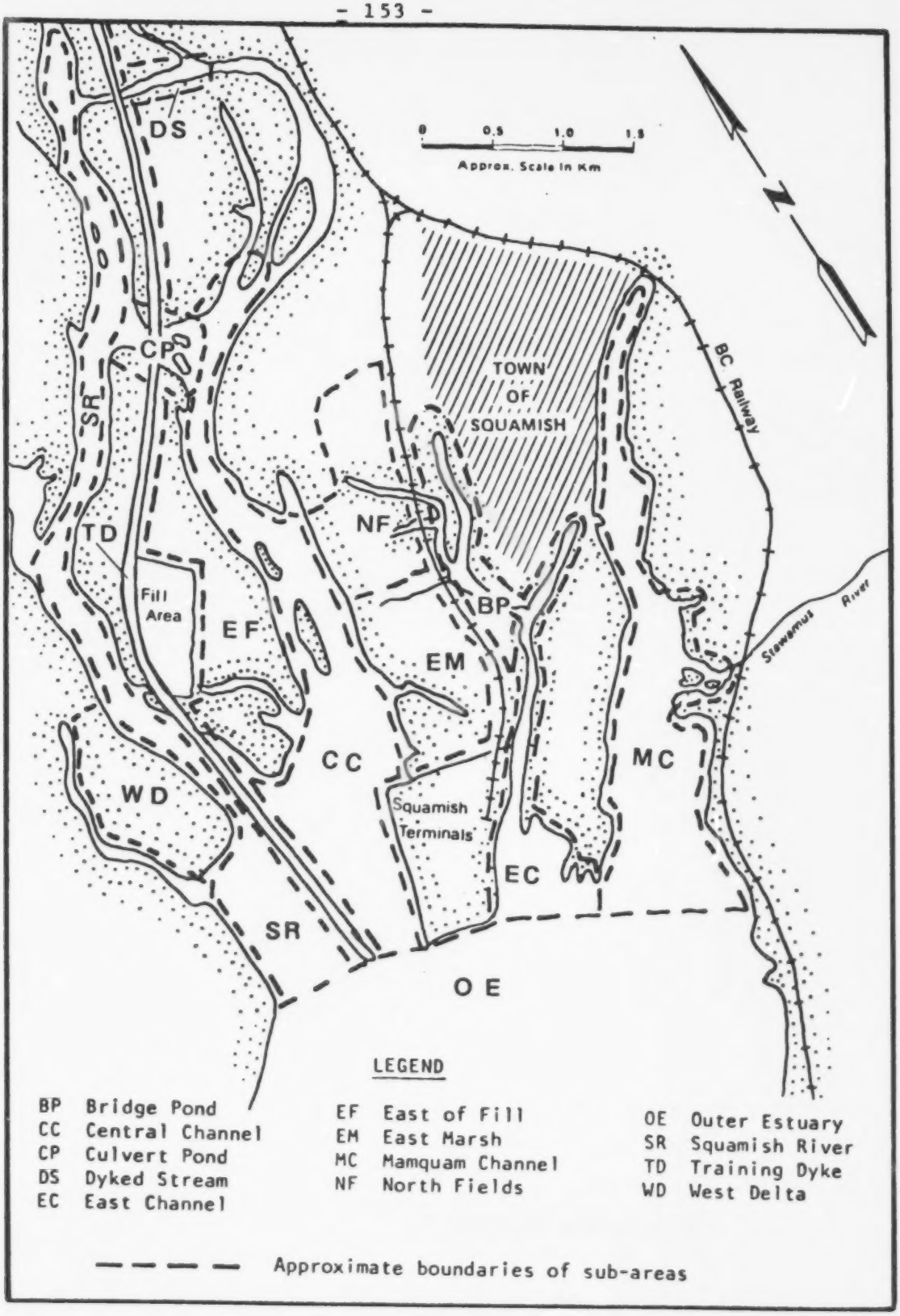
B.2 Numbers of bufflehead seen at the Squamish River estuary October 1972 to May 1973



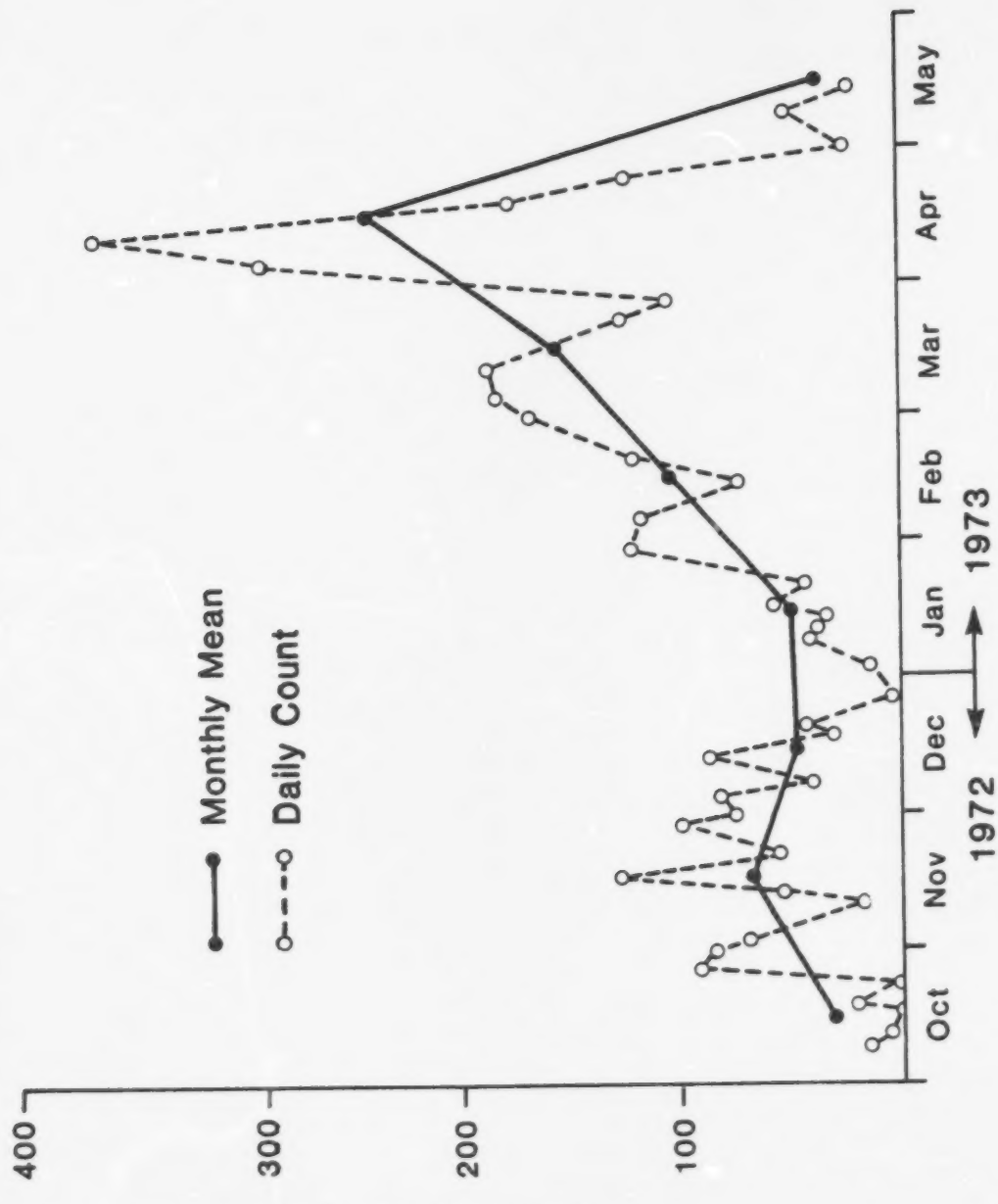
B.3 Numbers of mergansers seen at the Squamish River estuary October 1972 to May 1973



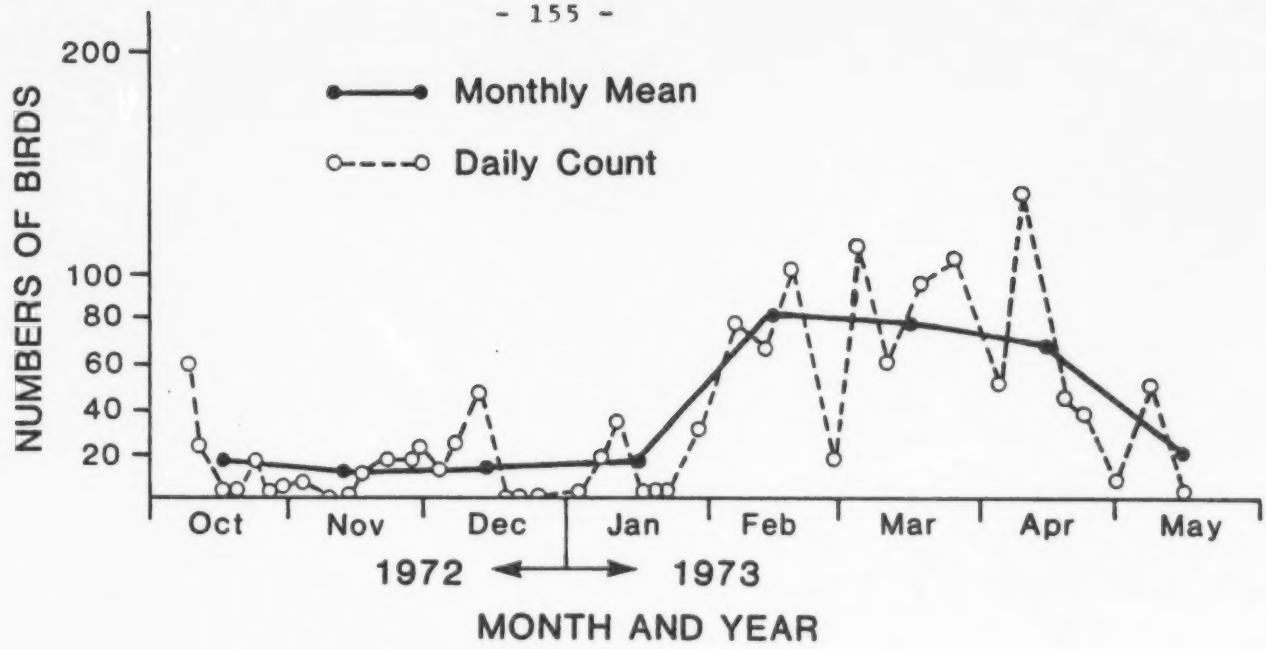
B.4 Numbers of scaup seen at the Squamish River estuary October 1972 to May 1973



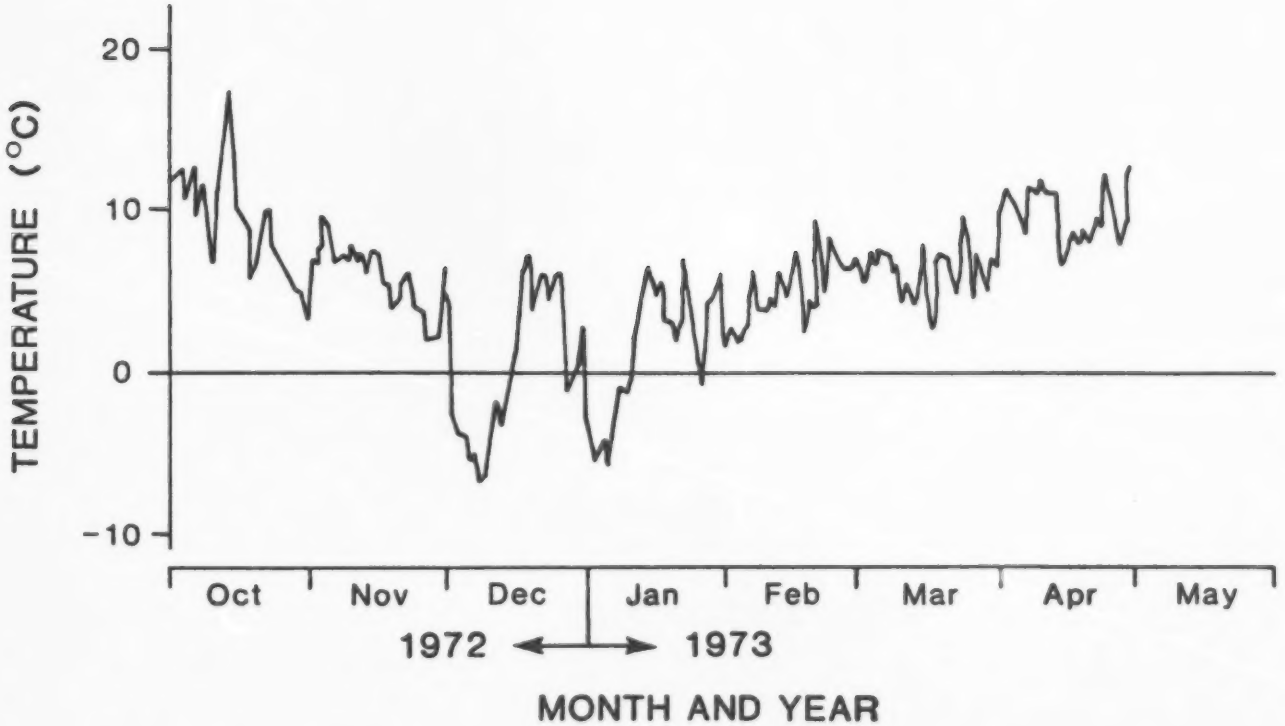
B.5 Sub-areas of the Squamish study area, C.W.S. bird studies, 1972-73



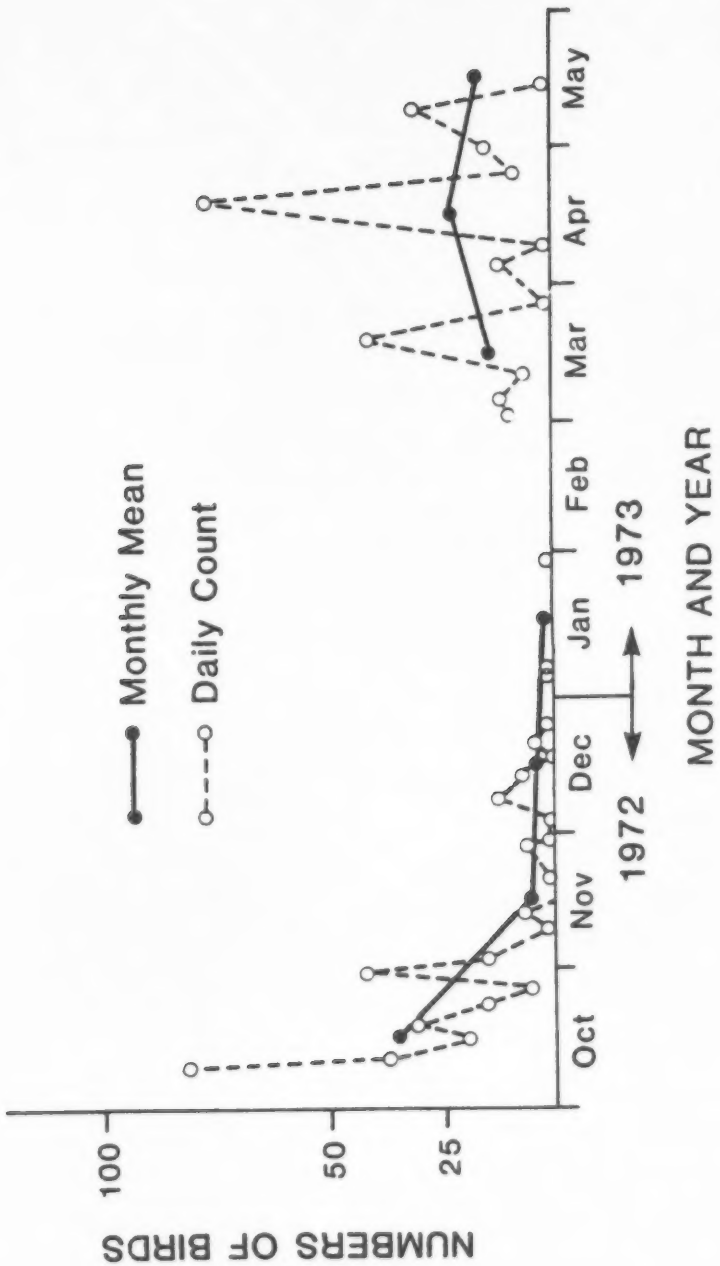
B.6 Numbers of mallards seen at the Squamish River estuary October 1972 to May 1973



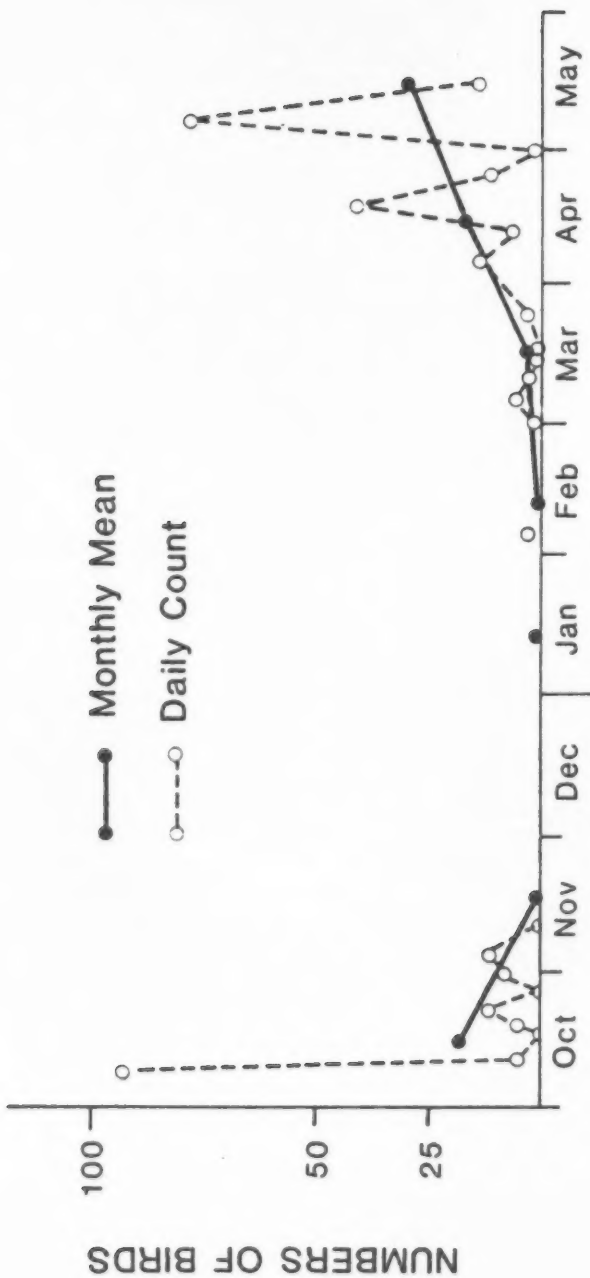
B.7 Numbers of pintail seen at the Squamish River estuary October 1972 to May 1973



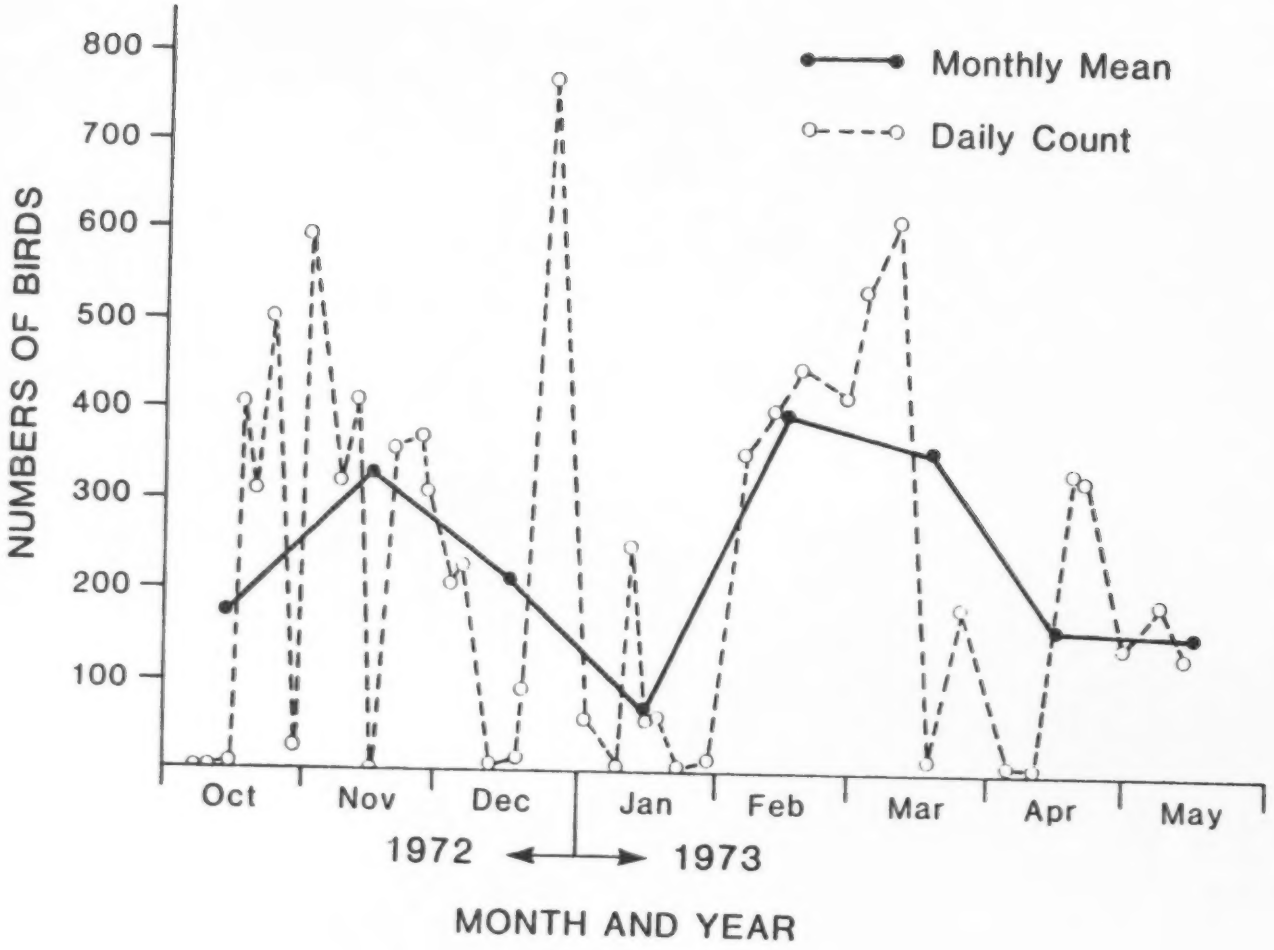
B.8 Mean daily temperature (°C) at Brittania Beach October 1972 to May 1973



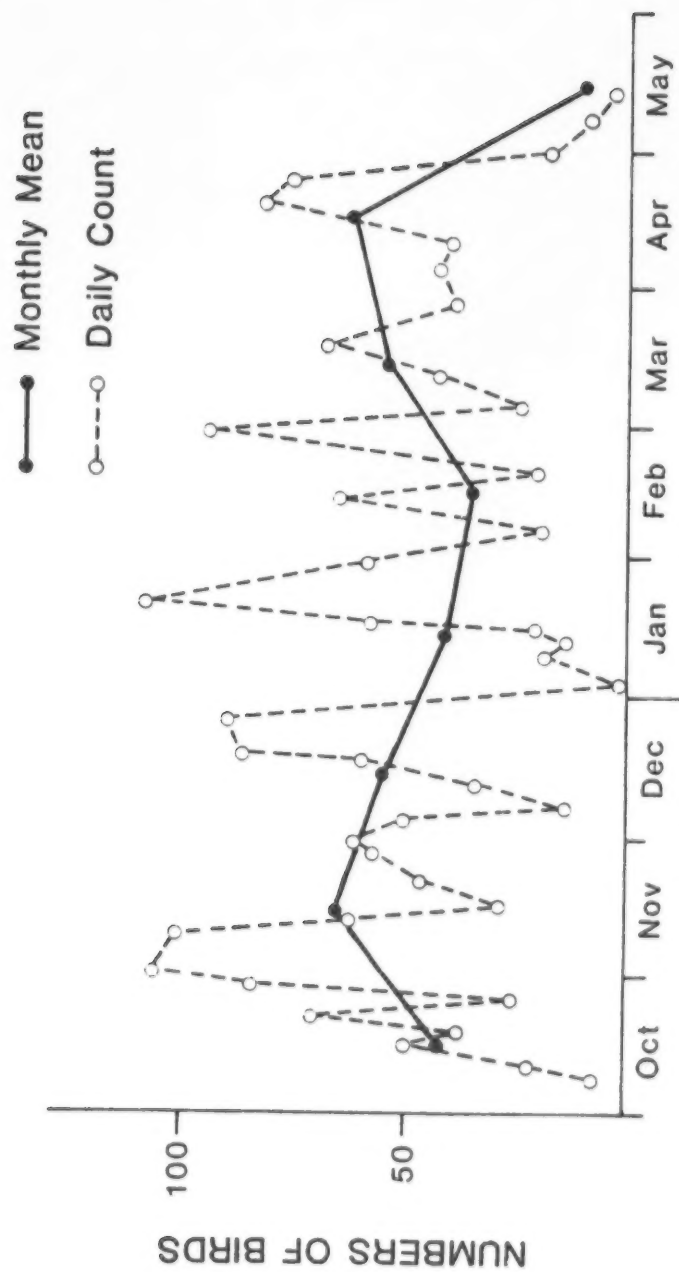
B.9 Numbers of green-winged teal seen at the Squamish River estuary October 1972 to May 1973



B.10 Numbers of American wigeon seen at the Squamish River estuary October 1972 to May 1973



B.11 Numbers of western grebes seen at the Squamish River estuary October 1972 to May 1973



B.12 Numbers of horned grebes seen at the Squamish River estuary October 1972 to May 1973

SQUAMISH RIVER ESTUARY HABITAT CLASSIFICATION

SCALE: 1:10 000

Province of British Columbia — Ministry of Environment
TERRESTRIAL STUDIES BRANCH

U.T.M. Grid – Zone 10 (1975)
Date of Photos: Sept. 1976
Control by: Field Operations Division
Contour Interval: 1 and 2 metres.

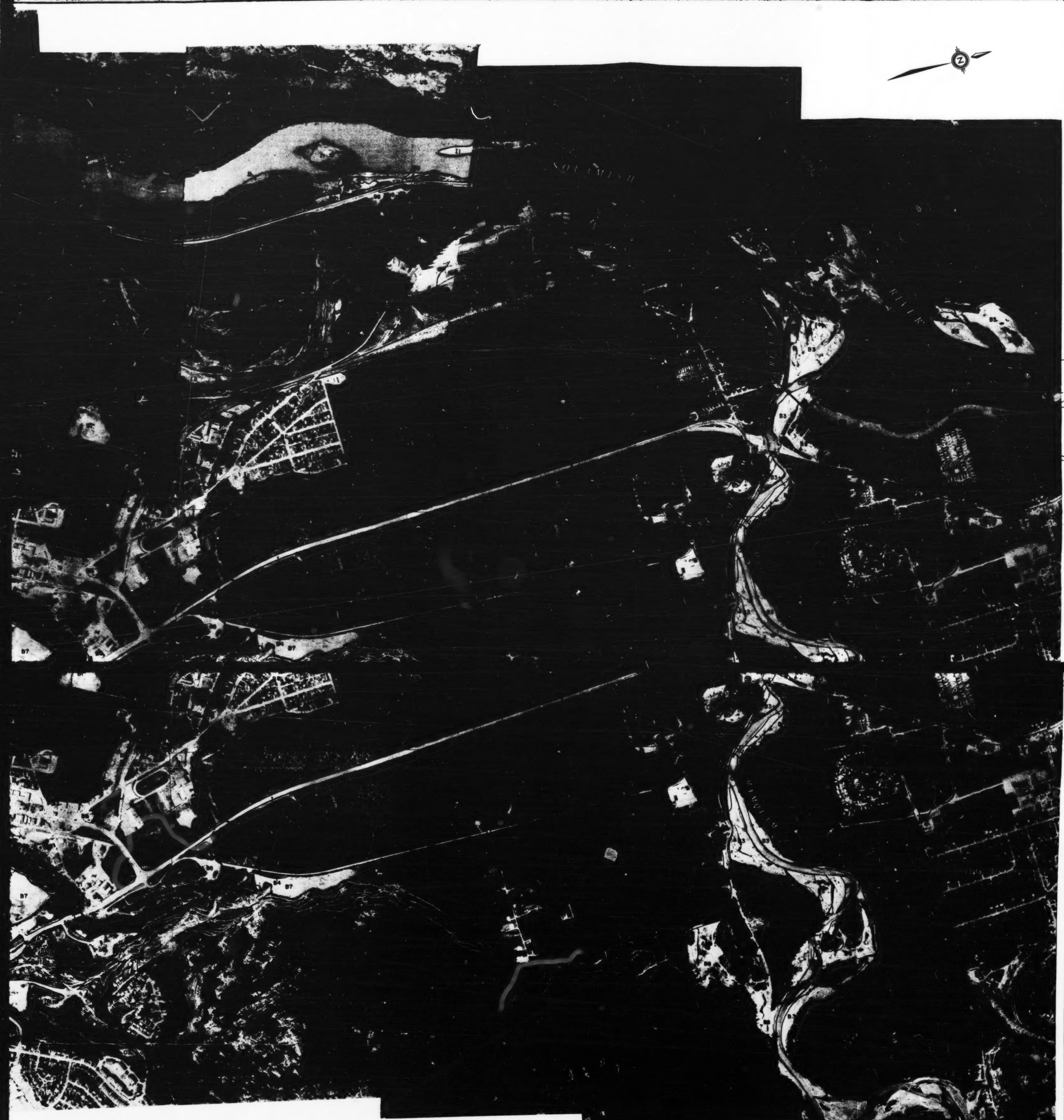
Orthophoto prepared by Surveys and Mapping Branch.

Composite from Project 77·166T·0 sheets 19–22 for Terrestrial Studies Branch.

LEGEND

HABITAT ZONES	O Open Water	I Intertidal	B Backshore/Low
HABITAT CLASSES	1 Deep water marine 2 Shallow water marine 3 Shallow water riverine 4 Brackish slough	1 Open mud/sand flats 2 Tidal drainage channels 3 Low marsh 4 Intermediate marsh 5 Upper marsh	1 Estuarine mead 2 Estuarine shrub 3 Riverine gravel 4 Pioneer shrub 5 Deciduous fores 6 Mixed deciduou 7 Disturbed - und 8 Developed - ind

—— Management Plan Study Boundary



LEGEND

TAT ZONES	O Open Water	I Intertidal	B Backshore/Lowland	U Upland
TAT CLASSES	1 Deep water marine 2 Shallow water marine 3 Shallow water riverine 4 Brackish slough	1 Open mud/sand flats 2 Tidal drainage channels 3 Low marsh 4 Intermediate marsh 5 Upper marsh	1 Estuarine meadow 2 Estuarine shrub 3 Riverine gravel bars 4 Pioneer shrub 5 Deciduous forest 6 Mixed deciduous-coniferous forest 7 Disturbed - undeveloped 8 Developed - industrial/residential	1 Pioneer shrub 2 Deciduous forest 3 Mixed deciduous-coniferous forest 4 Coniferous forest 5 Scrub/rock 6 Developed - industrial/residential

—— —— Management Plan Study Boundary (adjusted)